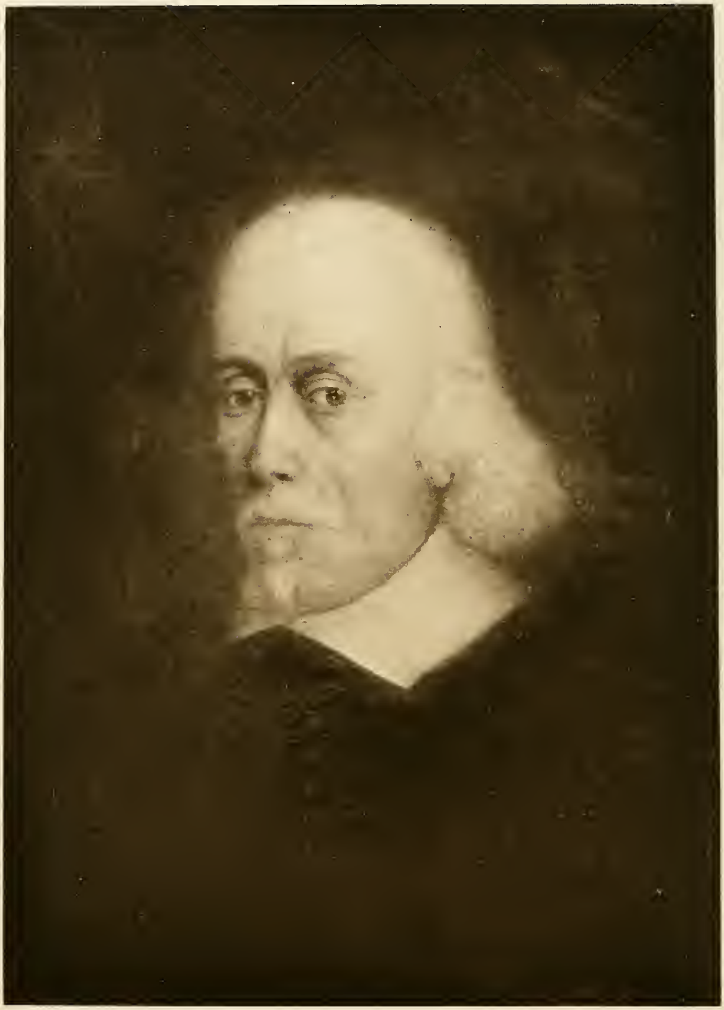
F. P. Vale.

The Toronto 20 & P.
Wash. D.C.

July 9/10

Thread of modern medical thought may take as its text Alkalines – cf Virgil's 2nd [illegible]



William Harvey, M.D.

from the Portrait in the National Portrait Gallery.

AN

Anatomical Dissertation upon the Movement of the Heart and Blood in Animals,

BEING

A STATEMENT of the DISCOVERY of THE CIRCULATION OF THE BLOOD.

BY

WILLIAM HARVEY, M.D.,

Physician-Extraordinary to King James the First; Physician-in-Ordinary to King Charles the First; and Professor of Anatomy in the Royal College of Physicians in London.

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1894.

PREFATORY MEMOIR.

DOCTOR WILLIAM HARVEY was the eldest son of *Thomas Harvey*, of *Folkestone*, by his second wife JOAN HALKE. He was born at *Folkestone* on the 1*st* of *April*, 1578. His father is described as a Jurat or Alderman, of *Folkestone*, where he was elected to the Office and Dignity of Mayor in the year 1600. Beyond this THOMAS HARVEY, the family genealogy lapses into trackless obscurity; although he is considered by a Genealogist of the Harveys* as 'apparently descended from or of the same branch 'of the family as Sir WALTER HARVEY, "Pepperer" Warden 'or Mayor of *London* 1272-3 who bore like arms,'—but of this vague relationship, which probably the Doctor himself never heard of, there is no satisfactory evidence.

THOMAS HARVEY was undoubtedly a highly respectable person as Burgess, Alderman and Mayor of *Folkestone*, which was then a small fishing town with a more or less romantic trade in smuggling, where he was probably engaged in some business occupation. By his second Wife *Joan*, whom he wedded in the year 1577, he had seven sons and two daughters, of whom DOCTOR HARVEY was the eldest. According to JOHN

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* See 'Miscellanea Genealogica et Heraldica,' 2nd Series, volume i., pp. 357, 388; also volume iii., p. 329, &c.—Genealogical Contributions by W. J. HARVEY—from which much of the genealogical data of this Memoir has been derived.

AUBREY*—who was an intimate friend of DOCTOR HARVEY—and to whom we are indebted for much interesting personal gossip respecting him—THOMAS HARVEY occupied, and his family were 'borne in the House which is now the Post-house, 'a fair stone-built house, which he gave to *Caius* College in '*Cambridge*, with some lands there in his Will. His brother '*Eliab* would have given any money or exchange for it because ''twas his father's, and they all borne there, but the Doctor '(truly) thought his memory could better be preserved this 'way.'—There is, however, no mention of this bequest in DOCTOR HARVEY'S Will; and the site of the house is now believed to be that which is at present occupied with the *Folkestone* branch of the Young Mens' Christian Association there.

THOMAS HARVEY placed his sons well out in life; some of them became Merchants of *London* trading with the East and the *Levant*, one of whom endowed the Grammar School at *Folkestone;* another was Member of Parliament for *Hythe* and held some office in the Royal Household. *William*, the eldest, was sent to the *King's* School at *Canterbury*, in the years 1588-93; and was admitted at *Gonville* and *Caius* College in *Cambridge* on the 31*st May* 1593; where he graduated in Arts, B.A., in the year 1597. In the year following, he proceeded to the then great Medical School at *Padua* where he obtained his Medical diploma on the 25*th April*, 1602, when twenty-four years of age. He then returned to *England*, received his Doctor's degree at *Cambridge:* and shortly afterwards married a daughter of Dr. LANCELOT BROWN of *London*, by whom he had no children; and entered upon medical practice in the City. In the year 1605 he lost his Mother by death, and she

* 'Lives of Eminent Men,' by JOHN AUBREY: London, 1813, 8vo. JOHN AUBREY was born in the year 1626: and first saw DOCTOR HARVEY in the year 1642, but did not become acquainted with him until the year 1651. JOHN AUBREY was well educated, and of a good family, but got into difficulties of 'lawsuits and lovesuits': a most genial, observant man, who says of himself: 'My head was always working, never idle, and even travelling 'did glean some observations, some whereof are to be valued.' He was one of the bearers at Harvey's funeral, and died in the year 1697.

was buried in the Chancel of the parish Church at *Folkestone*, where on its original brass plate—though relacquered, with some of the letters rubricated and otherwise 'restored' to be in keeping with its highly decorated surroundings—her quaint and beautifully expressed epitaph is still to be seen.

THOMAS HARVEY survived his Wife until the year 1623, when he died and was buried at *Hackney;* so that neither of the parents lived to know of their eldest son's discovery by which he was destined to render himself memorable through the ages to come.

DOCTOR HARVEY'S practice as a Physician appears to have been successful from the first and to have steadily increased in prosperity while it procured him various valuable professional appointments. He was elected a Fellow of the College of Physicians—an institution with which he will, as he wished, ever be memorably connected—on the *5th June*, 1607; and some years later he was appointed Physician-Extraordinary to King *James* the First; and later on, after the publication of his great Treatise, he was appointed Physician in Ordinary to King *Charles* the First, whom he attended during the Civil Wars.

It is supposed to have been about the year 1615, that DOCTOR HARVEY first set forth his views on the Circulation of the Blood during a course of Lectures, which were delivered at the College of Physicians: but it was not until the year 1628 that his great work '*De Motu Cordis*' was published, when it appeared from a foreign press at *Franckfort-on-the-Maine* which was, it is said, the great centre of the book-publishing trade at that time.

For many years DOCTOR HARVEY had by careful examinations of, and experiments made upon, the bodies of animals, endeavoured to ascertain the movements and functions of the heart; and the conclusions which he formed respecting them were such that he could not accept the generally received views of preceding Physiologists, who had specially studied and written upon the subject. His conclusions were not arrived at without considerable labour and difficulty, so much so that, it

is said, at one time he found the matter so beset with difficulties that he was inclined to agree with *Fracastorius*, that the movements of the heart and their purposes could be comprehended by God alone. This despair was but momentary and soon overcome; and perhaps it was then, when, as he says 'I began 'to think whether there might not be a MOVEMENT IN A CIRCLE'—and thus the great Truth was revealed to him.

DOCTOR HARVEY'S work '*De Motu Cordis*,' setting forth his discovery, was on its publication, as is well known, generally rejected:* but it is not perhaps generally recollected that *no ocular demonstration of the actual Circulation of the Blood was possible at that time;* nor until the introduction of the microscope which was not till after his time. In this consists DOCTOR HARVEY'S true greatness that he arrived at his discovery by faith in inductive reasoning as an infallible guide to Truth. He was indeed a true Seer; and his discovery is the most beneficial to mankind that has yet been made.

It is pathetic to consider, were it not that it ennobles DOCTOR HARVEY'S discovery, that he never saw the blood actually circulating: the only magnifying glass then used or known was the ordinary reading glass of to-day. It was reserved for one MARCELLUS MALPIGHI, of *Crevalcuore*, who used the microscope, to see the blood actually in circulation as exhibited in the lung of a frog—which he announced three or four years after DOCTOR HARVEY'S death.

In the year 1651 DOCTOR HARVEY'S work on 'Generation' appeared; and in the year 1654 he was elected President of the College of Physicians, to which he was a great Benefactor and made considerable additions to the building which were destroyed in the Great Fire. He also made a settlement of funds upon the College one portion of the interest of which was to be for the Librarian's salary and the other to be devoted to the

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* *Aubrey* says that he heard *Harvey* say 'that after his book on the 'Circulation of the Blood came out, he fell mightily in his practice, and was 'believed by the vulgar that he was crack-brained, and all the physitians 'were against him.'

annual delivery of a solemn Oration in commemoration of those who had been Benefactors to the College. This Oration, now known as the Commemorative Oration, is still annually delivered on St. *Luke's* Day when DOCTOR HARVEY'S work and memory are affectionately revered. At the recent Oration delivered by Doctor LAUDER-BRUNTON, it was shown how DOCTOR HARVEY'S discovery still lives and works, and that from his idea of the Circulation, had grown all modern ideas of disease and the mode and action of drugs.

Of DOCTOR HARVEY'S personal appearance and disposition we have the testimony of his friend JOHN AUBREY who thus describes him: 'He was not tall, but of the lowest stature,* 'round faced, olivaster (like wainscot) complexion, little eie, 'round, very black, full of spirit, his haire was black as a raven, 'but quite white twenty years before he died. . . . In temper 'he was like his brothers, very choleric, and in his younger 'days he wore a dagger, as the fashion then was, which he 'would be apt to draw out upon every occasion'—though it is not recorded that he ever did so to anyone's injury.—In visiting his patients he 'rode on horseback with a foot-cloath, his 'man following on foot, as the fashion then was, which was 'very decent, now quite discontinued. The judges rode also 'with the foot-cloathes to *Westminster* Hall. . . . He was 'always very contemplative and was wont to frequent the leads 'of Cockaine-house, which his brother *Eliab* had bought, 'having there his several stations in regard to the sun and the 'wind, for the indulgence of his fancy . . . he had caves made 'in the ground, in which he delighted in the summer time to 'meditate.' He also loved darkness, saying that he could then better contemplate.

* In the face of this evidence it is strange to see the incongruous Statue of DOCTOR HARVEY, which was erected on the *Folkestone* Leas in the year 1881. In this Statue he is represented as of colossal size, standing with a large heart in his left hand, from which the ventricles are seen protruding, resembling in their size and appearance the ends of iron gas-pipes: while his right hand is extended as if in the act of demonstrating his views. The stained-glass window to his memory which was placed in *Folkestone* Church is a much more pleasing memorial.

The best portrait of DOCTOR HARVEY is believed to be that by *Jansen* at the Royal College of Physicians; and it is regrettable that permission to reproduce it for this work—which is of so much interest in connection with him who was so great a Benefactor to, and so illustrious a Fellow of, the College—was withheld. The Portrait prefixed to this volume is from that in the National Portrait Gallery, which was once the property of DOCTOR MEAD, and has been twice engraved: it is a pleasing and an authentic likeness.

As DOCTOR HARVEY advanced in years he did not practise his profession except in special cases. He appears to have been generally free from physical infirmity; but towards the end of his life he was much afflicted with the gout, though at the close, his transition through Death was easy and his great spirit passed away on the evening of the 3*rd* of *June*, 1657, within ten months of his eightieth birthday.

After DOCTOR HARVEY'S death there was a rumour that he had ended his struggles by taking opium, which his friend *Aubrey* very strongly denies, and says 'It is now fitt and but 'just that I should endeavour to undeceive the world in a 'scandal that I find strongly runnes of him, wch I have mett 'amongst some learned young men, viz., that he made himself 'away, to putt himself out of his paine by opium; not but that, 'had he laboured under great paines, he had been readie 'enough to have donne it; I do not deny that it was not 'according to his principles on certain occasions to . . . [*sic*] 'but the manner of his dyeing was really and *bonâ fide* thus, 'viz., the morning of his death about 10 o'clock, he went to 'speake, and found he had the dead palsey in his tongue; then 'he sawe what was to become of him, he knew there was then 'no hopes of his recovery, so presently sends for his young 'nephews to come up to him to whom he gives one his watch '('twas a minute watch with which he made his experiments), 'to another, another remembrance, *&c.*, made sign to . . .

'*Sambroke,* his Apothecary, in *Black Fryars,* to lett him blood
'in the tongue, which did little or no good and so he ended
'his dayes.'

According to *Aubrey,* DOCTOR HARVEY died in *London* but the Harvey Genealogist states that it was at his brother's house at *Roehampton.* His remains were encased in lead and laid to rest in the family vault in *Hempstead* Church on the 26*th June,* 1657.

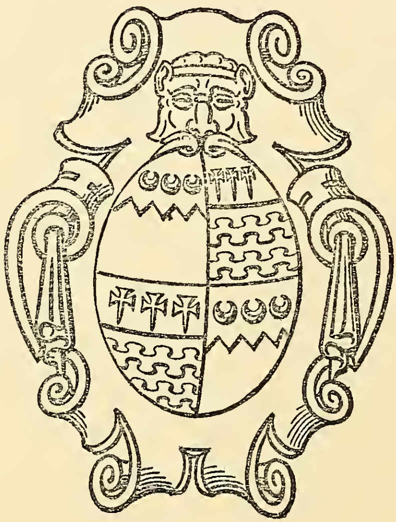
In *January,* 1882, the Tower of *Hempstead* Church collapsed; and the further preservation of DOCTOR HARVEY'S remains—which were lying encased in their original lead cerements, in the Harvey vault beneath the Church—was considered by the College of Physicians and the family representatives. It was at first proposed to re-inter them in *Westminster* Abbey beneath a thick glass plate. This idea was, however, abandoned; and a marble sarcophagus was erected in the centre of the *Harvey* Chapel of *Hempstead* Church: and on St. *Luke's* Day (the day of the annual Commemorative Oration) the 18*th* of *October,* 1883, in the presence of the family representatives, the President, the Office bearers, and some of the Fellows of the College of Physicians and the officiating Clergy, the remains were reverently transferred to their new, and it may be hoped, final resting-place within the sarcophagus together with a copy of his works and a Roll recording the incidents of the Translation.

Those who may desire fuller information respecting DOCTOR HARVEY than it is practicable to give within these brief limits are referred to his life by the late DOCTOR WILLIS, published in 1878, the year of his own death. DOCTOR WILLIS truly revered DOCTOR HARVEY'S memory and has with particular and unusual ability set forth his discovery and considered it in connection with the views of preceding Physiologists. DOCTOR HARVEY'S Works, translated and edited by DOCTOR WILLIS, were published by the *Sydenham* Society in the year 1847.

In the Museum at *Folkestone* is an ancient pestle and Mortar which is exhibited as having been used by DOCTOR HARVEY for compounding his drugs. The Mortar which is composed of

bell metal bears the following encircling inscription—1625. SOLI . DEO . GLORIA . MICHAEL . BVRCERHVVS . ME . FECIT. There is no evidence of its ever having been in the possession of DOCTOR HARVEY: it is, however, contemporary with him.

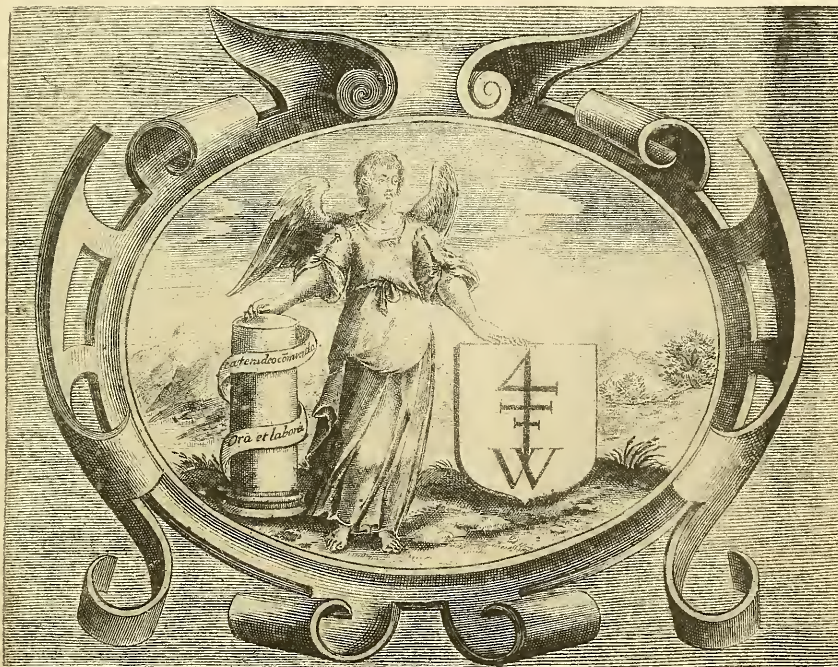
B.



Cartouche displaying the *Harvey* Coat-of-Arms, copied from DOCTOR HARVEY'S Monument in *Hempstead* Church.

EXERCITATIO ANATOMICA DE MOTV CORDIS ET SANGVINIS IN ANIMALIBVS,

GVILIELMI HARVEI ANGLI,
Medici Regii, & Professoris Anatomiæ in Collegio Medicorum Londinensi.



FRANCOFVRTI,
Sumptibus GVILIELMI FITZERI.

ANNO M. DC. XXVIII.

Sereniſsimo & Inuictiſsimo

CAROLO, MAGNÆ BRITANNIÆ, FRANCIÆ, ET HYBERNIÆ REGI, FIDEI DEFENSORI.

SErenisſime Rex,

Cor animalium, fundamentum eſt vitæ, princeps omnium, Microcoſmi Sol, à quo omnis vegetatio dependet, vigor omnis & robur emanat. Rex pariter regnorum ſuorum fundamentum, & Microcoſmi ſui Sol, Reipublicæ Cor eſt, à quo omnis emanat poteſtas, omnis gratia provenit. Quæ de motu cordis hîc ſcripta ſunt, Majeſtati tuę (vti huius ſeculi mos eſt) offerre eò magis auſus ſum, quòd ad hominis exemplum hu-

mana pene omnia, & ad cordis, Regis plurima. Regi itaque non inutilis cordis ſui notitia, tanquam actionum diuinum Exemplarium: (ſic paruis componere magna ſolebant.) Poteris ſaltem Regum optime, in faſtigio rerum humanarum poſitus, vnâ operâ & humani corporis principium & Regię ſimul poteſtatis Tuę effigiem contemplari. Suſcipe itaq;, humilime precor; Sereniſſime Rex vſitata benignitate & clementia de corde noua hæc, qui ipſe nouus ſplendor huius ſeculi, & totum vere cor es, princeps virtute abundans, ac gratia; cui acceptum iure merito referimus, quicquid noſtra Anglia boni, quicquid vita noſtra iucundi, habet.

Auguſtiſſimæ Maieſtatis Tuæ

deuotiſſimus ſeruus

GVILIELMVS HARVEIVS.

Excellentiss^o *& Ornatiss. Viro D.*

D. ARGENT,

COLLEGII MEDICORVM LONDINENS. PRÆSIDI AMICO SVO

singulari cæterisq; Doctiss. Medicis Collegis suis amantiss.

S. P. D.

MEam de motu & vsu cordis, & circuitu sanguinis sententiam E. D. D. antea sæpius in prælectionibus meis Anatomicis aperui novam: sed iam per nouem & amplius annos multis ocularibus demonstrationibus in conspectu vestro confirmatam, rationibus & argumentis illustratam, & ab obiectionibus doctissimorum & peritissimorum Anatomicorum liberatam, toties ab omnibus desideratam, à quibusdam efflagitatam, in lucem & conspectum omnium hoc libello pro-

duximus. Quem nisi vobis transmissum E. D. D. minus sperarem prodire posse integrum & tutum, cum pene omnium illarum obseruationum, ex quibus aut veritatem colligo, aut errores redarguo, è vobis plurimos & fide dignos appellare possum testes, qui dissectiones meas vidistis, & ocularibus demonstrationibus eorum, quæ hic ad sensum palàm asseuero, assistere candidè & astipulari consueuistis. Et cum contra receptam viam, per tot secula annorum ab innumeris, iisq; clarissimis doctissimisque, viris tritam & illustratam; sanguinem iter nouum metiri suum & reuoluere solus iste liber affirmaret; arroganter nimis factum, ne videretur, libellum istum per aliquot abhinc retro annos alioquin perfectum, vel in publicum exire vel transfretare si permisissem, summopere verebar: Nisi prius vobis proposuissem, & per autopsiam confirmassem, vestris dubiis & obiectionibus respondissem, & Præsidis ornatissimi censuram in fauorem accepissem. Persuasissimum veruntamen habui, quod si coram vobis nostroq; Collegio tot tantisque viris doctissimis nobilitatō, propositum sustinere potuerim, ab aliis tum demum minus pertimescendum, & iam illud, quod mihi

à vobis

à vobis, ob amorem veritatis, contigit vnicum ſolatium, ab omnibus aliis qui ſimiliter ſint philoſo hati non minus eſſe ſperandum. Philoſophi enim veri, qui amore veritatis & ſapientiæ flagrant, nunquam ſe tam σοφȣ̀ς, ſapientia plenos reperiunt, aut ſuo ſenſu abundant, quin veritati, à quocunque & quandocunque venerit, locum dent. Nec tam anguſti animi vt credant quamuis artem aut ſcientiam adeo omnibus numeris abſolutam & perfectam à veteribus traditã, vt aliorũ induſtriæ, & diligentiæ nihil ſit reliquum: cum profiteantur plurimi, maximam partem eorum quæ ſcimus, eorum quæ ignoramus minimam eſſe, nec ita traditionibus & præceptis quorumcunque addicti, inſervire ſe patiuntur Philoſophi, & libertatem perdũt, ne oculis propriis fidem adhibeant, nec ita in verba iurant antiquitatis magiſtræ, vt veritatem amicam in apertis relinquant, & in conſpectu omnium deſerant. Sed ſicut credulos & vanos, omnia prima facie admittere & credere, ita manifeſta ſenſui non videre, & Luce meridianã diem nõn agnoſcere, ſtupidos & inſenſatos pariter exiſtimant. Et non minus poetarum fabulas, & vulgi deliramenta, quam Scepticorum epochen in via philoſophica

decli-

declinare docent. Omnes item ſtudioſi, boni, honeſtique, nunquam ita paſſionibus indignationis, inuidiæ, obrui mentem ſinunt, quo minus audiant æquo animo quæ pro veritate proferantur, aut rem vere demonſtratam intelligant. nec turpe putant mutare ſententiam ſi veritas ſuadet & aperta demonſtratio: nec errores, licet antiquiſſimos deſerere arbitrantur inhoneſtum. Cum optime norint quod humanum ſit errare, decipi, & quod caſu multa reperta eſſe contingat quæ diſcere quiuis à quouis poſſit, à iuuene ſenex, à ſtulto intelligens.

Verum iſto tractatu, Collegæ Amantiſſimi, in authorum & ſcriptorum Anatomicorum nominibus, operibus & ſententiis recenſendis, exagitandis memoriam meam, & lucubrationes, multamque lectionem & magnum volumen oſtentare nolebam. Tum quod non ex libris, ſed ex diſſectionibus, non ex placitis Philoſophorum, ſed fabrica naturæ diſcere & docere Anatomen profitear. Tum quod neque è veteribus quemquam debito honore defraudare, neque è poſterioribus quemquam irritari æquum cenſeam, aut moliar. Neque cum iis qui in Anatomicis antecelluerunt, & me docuerunt, manus conſerere, aut dimicari honeſtum putem. Accedit, quod nec falſitatis crimen, in quempiam

piam veritatis ſtudioſum mea ſponte inurere vellē, nec quenquam erroris labe inſimulare. Sed ſolam veritatem ſector, & omnem tum operam, tum oleū eò contuli, vt aliquid bonis gratum, doctis commodum, & rei litterariæ vtile in medium proferre poſſim. Valete Domini D. Excellentiſ. & Anatomico veſtro fauete

GVILIELMO HARVEO.

PROOEMIVM

Quo demonstratur quod quæ hactenus scripta sunt de motu, & vsu cordis & arteriarum minus firma esse.

DE cordis arteriarumque motu, pulsu, actione, vsu, & vtilitatibus cogitanti, operæpretium est, quæ prius ab aliis mandata sunt literis, euoluere, quæ vulgo iactata & tradita, animaduertere, vt quæ recte dicta, confirmentur: quæ falsa dissectione anatomica, multiplici experientia, diligenti, & accurata obseruatione emendentur.

Pene omnes huc vsque Anatomici, Medici, & Philosophi supponunt cum Galeno, eundem vsum esse pulsus, quem respirationis, & vna re tantum differre, quod ille ab animali hæc à vitali facultate manet: reliquis, vel quod ad vtilitatem, vel quod ad motus modum spectat similiter se habentibus, vnde affirmant (vt Hieronymus Fabr. ab aq. p. libro suo de respiratione *nuperrime edito) quod quoniam non sufficit pulsus cordis, & arteriarum ad euentandum, & refrigerandum; ideo à Natura pulmones circa cor fabrefactos esse. Hinc patet quod quæcunque dixerint priores de Systole, & Diastole, de motu cordis & arteriarum, hæc omnia ad pulmones respicientes eos tradidisse.*

Cum vero aliter se habeat motus, & constitutio cordis, quam pulmonum, aliter arteriarum, quam pectoris, alios exinde, vsus, & vtilitates exoriri verisimile est, differreque plurimum cordis, & similiter

ſimiliter Arteriarum pulſus, & vſus, à pectoris & pulmonum. Si enim iiſdem vſibus inſeruiant pulſus, ac reſpiratio, & in Diaſtole introſumant aërem in cauitates ſuas arteriæ (vti vulgo dicunt) & in Syſtole per eoſdem poros carnis, & cutis fuligines emittant, nec non medio tempore inter Syſtolem, & Diaſtolem aërem contineant; & quouis tempore aut aërem, aut ſpiritus, aut fuligines. Quid itaque reſpondeant Galeno, qui librum ſcripſit, Natura ſanguinem contineri in arteriis, & nihil præter ſanguinem, nimirum neque ſpiritus, neque aërem, ſicut ab experimentis, & rationibus in eodem libro *facile colligere licet. Et ſi in Diaſtole replentur arteriæ ab aëre introſumpto, in maiori pulſu, maiori ſubeunte aëris copia: ergo magno exiſtente pulſu, ſi totum corpus in balneum immerſeris, vel aquæ, vel olei, neceſſe eſt pulſum ſtatim aut minorem eſſe, aut tardiorem multo: cum per corpus ambientis balnei, aërem intra arterias permeare difficilius ſit, ſi non impoſſibile. Similiter, cum omnes arteriæ tàm profundæ, quàm cutaneæ, eodem tempore, & pari velocitate diſtendantur; quomodo poterit aër tàm libere, & celeriter per cutem, carnem, habitumque corporis in profundum pertranſire, quam per cuticulam ſolam. Et quomodo Embryonum arteriæ forinſecus in cauitates ſuas aërem per ventrem maternum, & per corpus vteri attrahant? Vel quomodo Phocæ, Balenæ, Delphines, cetaceum omne genus, & piſces omnes in profundo maris arteriarum ſuarum Diaſtole, & Syſtole, per immenſam aquæ maſſam celeri pulſu aërem introſumunt, & emittunt. Dicere vero quod aërem implantatum in aqua abſorbeant, & in aquam fuligines ſuas reddant, figmento haud abſimile. Et ſi in Syſtole arteriæ per poros carnis, & cutis, fuligines è cauitatibus illorum expellunt, cur non item ſpiritus, quos dicunt etiam in illis contineri, cum ſpiritus multo tenuiores fuliginibus ſint. Et ſi cum in Syſtole, tum in Diaſtole aërem arteriæ accipiunt, & reddunt, vti pulmones in reſpiratione; cur non & hoc faciunt inflicto per*

arteriotomiam vulnere & sectione trachææ per vulnus, aërem ingredi, regredi duobus contrariis motibus, palam est: Sectâ vero arteriâ statim vno continuo motu sanguinem vi protrudi, & non aërem, vel ingredi, vel regredi manifestum est. Si pulsus arteriarum partes corporis refrigerant, & euentant uti pulmones ipsum cor; quomodo dicunt vulgo arterias à corde in partes singulas vitalem sanguinem differre refertissimum spiritibus vitalibus? qui partium calorem faueant, sopitum suscitent, & quasi absumptum resarciant, & quomodo (si ligaueris arterias) statim partes non modo torpent, frigent, & quasi pallidæ cernuntur, sed & ali tandem desinunt, quod secundum Galenum contingit, quia calore, qui per omnes partes superne à corde confluxerat, priuatæ sint: cum hinc pateat magis arterias calorem partibus deferre, quam refrigerium, & euentationem. Præterea quomodo Diastole simul spiritus à corde attrahat, ad calefaciendas partes, simulq; ab externo refrigerium? Amplius tametsi iisdem vsibus pulmones, arterias, & cor inseruire aliqui affirment, tamen cor spirituum officinam esse, & arterias spiritus continere, transmittere etiam dicunt: Pulmones autem spiritus facere, aut retinere contra Columbi opinionem, negant. Quin & cũ Galeno, quod sanguis contineatur in arteriis, & non spiritus, contra Erasistratum asseuerant. Videntur istæ opiniones ita inter se pugnare, & sese inuicem refellere, vt omnes non merito sint suspectæ. Sanguinem in arteriis contineri, & arterias solum sanguinem deferre tum experimento Galeni, tum in arteriotomia, tum in vulneribus manifestum est, cum ab vna arteria dissecta, hoc etiam Galenus affirmat plurimis in locis vnius semihoræ spatio totam massam sanguinis ab vniuerso corpore, magna, & impetuosa profusione exhaustam fore, experimentum Galeni tale est. Si (*inquit*) funiculo arteriam vtrinq; ligaueris & medio rescisso secundum longitudinem, quod inter duas ligaturas in arteriis comprehensum erit, nihil præter sanguinẽ esse reperies: *& sic probat sanguinẽ solum continere. Vnde etiã similiter nobis ratiocinari licet:*

Galen. lib. quod sangui. cont. in arteriis.

licet: Si eundem sanguinem, qui venis similiter ligatis, & rescissis inest, inueneris in arteriis (quem in mortuis, & aliis animalibus sæpius ego expertus sum) eâdem ratione similiter concludere nos possumus, arterias eundem sanguinem, quem venæ, & nihil præter eundẽ sanguinem continere. Aliqui dum dissoluere difficultatem tentant, spirituosum, & arteriosum esse sanguinem affirmantes, tacite concedunt, arteriarum munus esse sanguinem à corde in vniuersum corpus deferre, & repletas sanguine arterias esse: Spirituosus n. sanguis, non minus sanguis est: Etiam sanguis prout sanguis, & qui in venis fluit, eum spiritibus imbui nemo negat. Quod si, qui in arteriis est sanguis vberiori spirituum copia turgeat, tamen existimandum est hos spiritus à sanguine inseparabiles esse, sicut illi in venis, & quod sanguis, & spiritus vnum corpus constituant (vt serum, & butyrum in lacte, aut calor in aquâ calidâ) quo corpore replentur arteria & cuius corporis distributionem à corde arteriæ præstant, & hoc corpus nihil aliud, quam sanguis est. Si vero hunc sanguinem in arteriis, è corde per arteriarum Diastolem attrahi dicunt, videntur astruere, quod arteriæ suâ distentione sanguine isto repleantur, & non aëre ambiente, vti prius: Nam si etiam aëre ab ambiente repleri dicant, quomodo & quando recipient è corde sanguinem? Si in Systole id fiat, continget impossibile; repleri arterias, cum attrahantur, vel repleri, & non distendi; Sin autem in Diastole, in duos vsus contrarios, & sanguinẽ, & aërem, & calorem, & frigus simul recipient; quod est improbabile. Amplius cum affirmant, simul Diastolẽ cordis, & arteriarũ esse, & simul Systolẽ, alterũ est inconueniẽs. Quomodo n. cum simul distenduntur duo corpora sic inuicẽ cõnata, alterũ ab altero attrahat, vel cũ simul cõtrahuntur, alterũ ab altero recipiat aliquid? Insuper forsan impossibile est, aliquid posse aliud corpus ita in se ipsũ attrahere vt distendatur, cũ distendi sit pati nisi vt spongia prius vi ab externis constricta, dũ redeat ad constitutionẽ suam naturalẽ. Tale autẽ aliquid in arteriis posse esse, difficile est fingere. Sed arterias distendi, quia replentur, vt sacculi, & vtres,

 atq;

atq; non repleri, quia distenduntur vt folles, facile, & aperte demonstrare me posse, & palam ante hac demonstrasse existimo: Attamen libr. quod sang. cont. in arter. *Galeni experimentum in contrarium sic se habet. Arteriam nudatam secundum longitudinem incidit, calamumque, vel concauam, per viam fistulam immittit, quo & sanguis exilire non possit, & vulnus obturetur.* Quoadusque (*inquit*) sic se habet, arteria tota pulsabit: cum primum vero obductum filum super arteriam, & fistulam in laqueum cōtrahens arteriæ tunicas calamo obstrinxeris, non amplius arteriam vltra laqueum palpitare videbis. *Nec ego feci experimentum Galeni, nec recte posse fieri viuo corpore ob impetuosi sanguinis ex arteriis eruptionem puto, nec obturabit sine ligatura vulnus fistula: & per fistulæ cauitatem vlterius prosilire sanguinem non dubito, tamen hoc experimento & probare videtur Galenus facultatem pulsificam per tunicas arteriarum, à corde manare, & quod arteriæ dum distendantur, ab illâ facultate pulsifica repleantur, quia distenduntur vt folles, non distendantur, quia replentur, vt vtres. Sed & in arteriotomia, & vulneribus contrarium manifestum est: sanguis enim saliendo ab arteriis profunditur cum impetu, modo longius, modo propius vicissim prosiliendo, & saltus semper est in arteriæ Diastole & non in Systole. Quo clare apparet, impulsu sanguinis arteriam distendi. Ipsa enim dum distenditur, non potest sanguinem tanta vi proijcere, potius aërem in se per vulnus attrahere deberet, secundum ea, quæ vulgò de arteriarum vsu iactata sunt. Nec crassities tunicarum arteriæ nobis imponat, facultatem pulsificam prouenire à corde per ipsas tunicas: Nam quibusdam animalibus arteriæ à venis nihil differunt, & extremis partibus hominis, & paruis disseminationibus arteriarum quales in cerebro, manu &c. nemo per tunicas, arterias à venis poterit distinguere: eadem enim vtrisq; tunica: in aneurismate præterea ex incisa vel exesa arteriæ genito, eadem omnino pulsatio*

cum

cum reliquis arteriis, & tamen non habet tunicam arteriæ. Hoc mecum doctissimus Riolanus lib.7. *attestatur. Neq; eundem vsum pulsus, ac respirationis quis existimet, quod iisdem causis vti, respiratio, crebriores, maiores, celeriores fieri cernat, vti cursu, ira, balneo, aut quouis calfaciente (vt dicit Galenus) Nam non solum illud experimentum est in contrarium (quod soluere Galenus nititur) cum ab immodica repletione pulsus existant maiores, respirationes minores; Sed & in pueris pulsus frequentes, cum respiratio interim rara. Similiter in timore, & curis, & anxietate animi, imo aliquibus in febribus pulsus celeres, frequentes, respirationes vero tardiores. Hæc & huiusmodi incommoda positas opiniones de pulsu, & vsu arteriarum, consequuntur: non minus forsan etiam ea, quæ de vsu, & pulsu cordis affirmantur, difficultatibus plurimis & inextricabilibus implexa sunt. Cor affirmant vulgo fontem, & officinam vitalis spiritus esse, quibus vitam singulis partibus largiatur, & tamen negant dextrum ventriculum spiritus facere, sed præbere duntaxat alimentum pulmonibus, vnde dicunt piscibus deesse dextrum ventriculum cordis, & omnino omnibus deest quibus non sunt pulmones: Et q dexter ventriculus cordis, pulmonũ gratia sit.*

1. *Cur (quæso) cum eadem pene constitutio sit vtriusq; ventriculi, eadem fabrica fibrarum, lacertulorum, valuularum, vasorum, auricularum, & eodem vterq; in dissectionibus referciatur sanguine, similiter nigricante, similiter grumescente: Cur (inquã) cum eadem sit vtriusq; actio, motus pulsus, variis eos vsibus, tam differentibus, existimemus destinatos fuisse? Si valuulæ tricuspides tres sub dextri ventriculi ingressu, impedimento sint sanguinis regressui in venam cauam, & si semilunares tres illæ in orificio arteriosæ venæ vt sanguinis regressum impedirent factæ sint: cur, cum similiter se habeant. sinistro ventriculo similiter sanguinis tum egressui, tum regressui impediendo factas esse, negemus.*

2. *Et cum magnitudine, forma, situ, omnino eodem pene modo*

sinistro

sinistro se habeant ventriculo, quo in dextro, cur dicunt hic spiritum egressui, & regressui impedimento esse in dextro vero sanguinis. Idem organon simile non videtur sanguinis, & spirituum motus similiter impedire apte posse.

3. Et cum meatus, & vasa sibi invicem respondeant magnitudine, videlicet, vena arteriosa, & arteria venosa; cur vnum priuato vsui destinetur, videlicet alendis pulmonibus, alterū publico.

4. Et quomodo probabile est (vti notauit Realdus Columbus) tanto sanguine opus esse ad nutritionem pulmonum, cum hoc vas, vena videlicet arteriosa, exuperat magnitudine vtrumq; ramum distributionis venæ cauæ descendentis cruralem.

5. Et (quæso) cum pulmones tam propè sint, & vas tam amplum existat, & ipsi continuo motu, quid est quod dextri ventriculi pulsu opus sit? & quid est quod Natura, gratia alendorum pulmonum, alterum ventriculum cordi adiungere necesse habeat.

Cum dicunt sinistrum ventriculum è pulmonibus, & dextro cordis sinu materiam attrahere, ad spiritus condendos; aërem videlicet & sanguinem, & pariter in aortam spirituosum sanguinem distribuere: & hinc fuligines, videlicet retro per arteriam venalem remitti in pulmones, illinc spiritus in aortam. Quid est quod separationem facit, & quod modo huc illuc spiritus fuligines citra permistionem aut confusionem commeant. Si tricuspides mitrales non impediunt egressum fuliginum ad pulmones, quomodo impedient aëris? Et quomodo semilunares prohibebunt regressum spirituum (subsequente Diastole cordis) ab aorta? Et omnino, quomodo dicunt per arteriam venalem spirituosum sanguinē distribui è ventriculo sinistro in pulmones, nec interim impediant tricuspides? cum affirmarint aërem per idem vas à pulmonibus in vētriculum sinistrū ingredi, cui eū egressui tricuspides illæ valuulæ impedimento esse voluerunt. Deus bone! Quomodo tricuspides impediunt aëris egressum, & non sanguinis.

Amplius

Amplius, cum venam arteriosam, vas amplum, magnum cum tunica arteriæ factum, non nisi priuato, & vni vsui (videl. alendis pulmonibus) destinarint: Cur arteriam venalem vix pari magnitudine cum tunica venæ molli, laxa, pluribus vsibus, tribus, vel quatuor videlicet fabrefactam asseuerant: volunt enim per ipsam aerem è pulmonibus in sinistrum ventriculum permeare: volunt similiter è corde in pulmones fuligines per ipsam remeare: volunt spirituosi sanguinis portionem à corde per ipsam in pulmones ad ipsos refocillandos distribui.

Si fuligines & aerem à corde illas, ad cor hunc per eundem tubulum volunt transmitti; tam cõtrariis motibus, & vsibus vnum vas, & vnam viam fabricare Natura solita non est, nec videre vspiam contigit.

Si fuligines, si aerem hac via permeare, remeare contendunt, vt per Bronchia pulmonum quare exsecta, vel incisa arteria venosa, neque aerem, neque fuligines reperire in dissectione possumus, & vnde semper refertam crasso sanguine arteriam venosam istam videmus, & nunquam aere; cum in pulmonibus, & aerem remanentem cernimus?

Si quis experimentum Galeni faceret, & cani adhuc viuenti trachaam incideret, & follibus pulmones aere impleret per vim, & distẽtos ligaret fortiter; Idem mox dissecto pectore multam aeris copiam in pulmonibus vsque ad extimam illorum tunicam inuenerit, sed neq; in arteria venosa, neque in sinistro ventriculo cordis quidquam. Si aerem è pulmonibus, in cane viuente, aut cor attraheret, aut pulmones transmitteret, multo magis hoc experimento id facere deberent. Imo in administratione Anatomica inflatis cadaueris pulmonibus, etiam aerem statim huc ingredi (si vlli essent meatus) quis dubitaret? Tam magni vero faciunt hunc vsum arteriæ venosæ, videlicet ad aerem è pulmonibus cordi deferendum: vt Hieronym. Fabr. ab. aq. p. huius vasis causa pulmones factos fuisse, & hanc esse præcipuam pulmonum particulam contendat.

Sed amabo, si aeri deferendo arteria venosa condita sit, cur eius constitutio est venæ?

Fistulis potius opus esset Natura (& quidem quales Bronchia sunt annularibus, vt semper pateant, & neque concidant, & vt omnino vacua sanguine permaneant ne humor aeris transitum impediat, vti manifestum est, quando pulmones pituita Bronchiis vel infarcta, vel paululum admissa laborant) sibilo, & strepitu oborto dum respiramus.

Minus toleranda illa opinio, quæ cum duplicem materiam (aereã, & sanguineam) necessariam esse ad spiritus vitales efficiendos supponit, sanguinem per mediastini cordis cæcas porositates de dextro in sinistrum ventriculum transudare, aerem per magnum vas Arteriam venosam è pulmonibus attrahi contendit: Et proinde in septo cordis porositates plures esse producendo sanguini accommodatas. Sed me hercule porositates nullæ sunt, neque demonstrari possunt.

Septi enim cordis substantia densior, & compactior est quauis altera corporis particula, exceptis ossibus, & neruis. Sed si adessent foramina, quomodo (cum simul vterque ventriculus distenditur, & dilatatur) alterum ab altero quidpiam, aut sinistrum sanguinem è dextro exhaurire possibile est? Et cur non potius dextrum spiritus ex sinistro, quam sinistrum sanguinem è dextro ventriculo per eadem foramina euocare crediderim. At mirum, & incongruum certe, sanguinem per cæcos obscurosque ductus, & aerem per patentissimos eodem instanti, commodius attrahi. Et cur quæso pro sanguinis transitu in sinistrum ventriculum ad cæcas, & inuisibiles porositates incertas, obscuras confugiunt, quando adest per arteriam venosam tam patens iter? mirum mihi certe est, quod per cordis septum, crassum, durum, densum, compactissimum viam facere, vel fingere potius maluerunt, quam per patens vas venosum, aut etiam per pulmonũ substantiam raram, laxam, mollissimam, spongiosam. Præterea si per septi substantiam sanguis permeare potuisset, aut è ventriculis imbibi, quid opus esset venæ, & arteria coronalis ramulis ad ipsius septi nutritionem diuaricatis? Quod notatu dignissimum, si in fœtu (quando omnia ra-

riora, molliora) Natura coacta fuit per foramen ouale ſanguinem in ſiniſtrum ventriculum è vena caua per arteriam venoſam traducere: Quomodo veriſimile poßit eſſe quod in adulto per cordis ſeptum iam denſius ætate factum tum commode nulloque negotio transfundat.

Andreas Laurentius lib. 9. cap. 11. Quæſtione 12. *authoritate Galeni* de lo. affect. lib. 6. cap. 7. *& experientia Hollerii fultus, aſſerit, & probat è cauitate pectoris ſeroſitates, & pus Empyricorum in arteriam venoſam abſorptum per ſiniſtrum ventriculum cordis, & per arterias cum vrina, vel cum fæcibus alui poſſe expelli recenſet. quinetiam in confirmationem caſum cuiuſdam Melancholici, qui ſæpius deliquium animi paſſus à paroxyſmo liberatus erat emißione vrinæ turbidæ, fœtidæ, acris: quo genere morbi tandem confectus, diſſecto cadauere, talis ſubſtantia, qualem mingebat, neque in veſica, neque in renibus vſpiam apparebat, ſed in cordis ſiniſtro ventriculo, & cauitate pectoris plurima: vnde gloriatur ſe horum affectuum talem prædixiſſe cauſam. Ego autem non poſſum non mirari, cum ipſe materiam heterogeneam poſſe eodem tractu euacuari diuinarat, & prædicauerat: quod iiſdem viis ſanguinem è pulmonibus in ſiniſtrum ventriculum ſecundum naturam deduci conuenienter cernere, aut aſſeuerare non potuit, aut noluit.*

Itaque ex his, & huiuſmodi plurimis patet, cum ea quæ dicta antehac à prioribus de motu, & vſu cordis, & arteriarum, aut inconuenientia, aut obſcura, aut impoßibilia diligentius conſiderãti appareant, vtile proinde admodum erit paulo penitius rem introſpicere, arteriarum, & cordis motus non ſolum in homine, ſed & aliis vniuerſis animalibus cor habentibus contemplari: Quin etiam viuorum diſſectione frequenti, multaque autopſia veritatem diſcernere, & inueſtigare.

EXERCITATIO Anatomica,

DE MOTV CORDIS ET SANGVINIS IN ANIMALIBVS.

Caput Primum.

Causa, quibus ad scribendum Author permotus fuerit.

CVM multis viuorum dissectionibus (vti ad manum dabantur) animum ad obseruandum primū appuli; quo cordis motus vsum, & vtilitates in animalibus per autopsiam, & non per libros aliorumque scripta inuenirem: Rem arduam plane, & difficultatibus plenam cōtinuo reperi, vt (cum Fracastorio) motum cordis soli Deo cognitum fuisse, penè opinarer. Nec enim quomodo Systolē, aut Diastole fieret, nec quando, aut vbi dilatatio, & constrictio existeret, recte potui internoscere, propter celeritatem scilicet motus qui in multis animalibus, nictu oculi, quasi traiecto fulgure, se in conspectum exhibuit, & subtraxit illico, Ita vt modo hinc Systolen, illinc Diastolen, modo è contra, modo varios, modo confusos fieri motus me existimabam cernere: vnde animus mihi fluctuabat, nec quid vel ipse statuerem, vel aliis crederem habebam, & motum cordis esse qualis Euripi fluxus, & refluxus Aristoteli, Andream Laurentium scripsisse non mirabar.

Tandem maiori indies, & disquisitione, & diligentia vsus, multa frequen-

ſicquenter, & varia animalia viua introſpiciendo, multis obſeruationibus collatis, & rem attigiſſe, & ex hoc labyrintho me extricatum euaſiſſe, ſimulque motum, & vſum cordis, & arteriarum, quæ deſiderabam, comperta habere me exiſtimabam. Ex quo non ſolum priuatim amicis, ſed etiam publice in prælectionibus meis anatomicis, Academico more, proponere meam in hac re ſententiam non verebar.

Quæ cum aliis (vti fit) placebat, aliis minus: hi conuellere, calumniari, & vitio vertere, quod à præceptis, & fide omnium Anatomicorum diſceſſerim: Illi rem nouam cum inquiſitu dignam tum maxime vtilem fore confirmantes, plenius ſibi explicatam poſcere. Tandem amicorum precibus, vt omnes meorum laborum participes fierent, partim etiam aliorum permotus inuidia qui dicta mea iniquo animo accipientes, & minus intelligentes, me publice traducere conabantur, vt omnes de me, & de re ipſa iudicium ferant, hæc typis mandare publice coactus fui: Sed & eo libentius, quod Hieronym. Fabr. ab aq.p. cum ſingulas pene animalium particulas, accurate, & docte peculiari tractatu delineauerat, ſolum cor intactum reliquit. Denique vt ſi quid reipub. literariæ ex opera mea vtile, & commodum hac in parte accederet, forſan recte feciſſe me conſtaret, nec alii omnino inertem me vixiſſe viderent, & quod ſenex ait in Comœdia (*Nunquam quiſquam ita bene ſubducta ratione ad vitam fuit,*

„ *Quin res, ætas, vſus aliquid apportet noui,*
„ *Aliquid admoneat, vt illa quæ te ſcire credas, neſcias.*
„ *Et quæ tibi putaris prima in experiundo repudies.)*

Illud forſan in cordis motu eueniat nunc, aut alii hinc ſaltem, hac data via, fœlicioribus freti ingeniis, rei rectius gerendæ, & melius inquirendi occaſionem capient.

CAPVT II.

Ex viuorum diſſectione, qualis ſit Cordis motus.

PRimum itaque in Cordibus, omnium adhuc viuentium animalium aperto pectore, & diſſecta capſula, quæ cor immediate circũcludit obſeruare licet. Cor aliquando mouere, aliquando quieſcere, & eſſe tempus in quo mouetur, & in quo motu deſtituitur.

Hæc manifeſtiora in cordibus frigidorum animalium, vt bufone, ſerpentibus, ranis, cochleis, gammaris, cruſtatis conchis, ſquillis, &

pisciculis omnibus: Fiunt etiam omnia manifestiora in cordibus aliorum, vt canis, porci, si eo vsque attente obseruaueris quoad emori cor, & languidius moueri, & quasi extingui incipiat: tum etenim tardiores, & rariores ipsius motus fieri, & longiores quietes, cernere aperte, & clare poteris, & motus qualis sit, & quomodo fiat, commodius intueri, & diiudicare licet. In quiete, vt in morte cor laxum, flaccidum, eneruatum, inclinatum quasi iacet.

In motu, & eo quo mouetur, tempore tria præ cæteris animaduertenda.

I. Quod erigitur cor, & in mucronem se sursum eleuat, sic vt illo tempore ferire pectus, & foris sentiri pulsatio possit.

II. Vndique contrahi, magis vero secundum latera, ita, vti minoris magnitudinis, & longiusculum, & collectum appareat. Cor anguillæ exemptum, & super tabulam aut manum positum hoc facit manifestú; çque etiam apparet in corde pisciculorum, & illis frigidioribus animalibus, quibus cor coniforme, aut longiusculum est.

III. Comprehensum manu cor eo quo mouetur tempore, duriusculum fieri, à tentione autem illa durities est, quemadmodum si quis lacertos in cubitu manu comprehendens, dum mouent digitos, illos tendi, & magis renitentes fieri percipiat.

IV. Notandum insuper in piscibus, & frigidioribus sanguineis animalibus, vt serpentibus, ranis, &c. illo tempore, quo mouetur cor albidioris coloris esse, cum quiescit à motu caloris sanguinei saturum cerni.

Ex his mihi videbatur manifestum; Motum cordis esse tentionem quandam ex omni parte, & secundum ductum omnium fibrarum, & constrictionem vndique, quoniam erigi, vigorari, minorari, & durescere in omni motu videtur, ipsiusque motum esse, qualem musculorú, dum contractio fit secundum ductum partium neruosarum, & fibrarum, musculi enim cum mouentur, & in actu sunt vigorantur, tenduntur, ex mollibus duri fiunt, attolluntur, incrassantur, & similiter Cor.

Ex quibus obseruatis rationi consentaneum est, Cor eo quo mouetur tempore, & vndique constringitur, & secundum parietes incrassescit: secundum ventriculos coarctari, & contentum sanguinem protrudere, quod ex quarta obseruatione satis patet, cum in ipsa tensione sua, propterea quod sanguinem in se prius contentum expresserit, albescit, & denuo in laxatione, & quiete, subingrediente de nouo sanguine in ven-

in ventriculum, redit color purpureus, & sanguineus cordi. Verum nemo amplius dubitare poterit, cum vsque in ventriculi cauitatem inflicto vulnere, singulis motibus, siue pulsationibus cordis in ipsa tēsione prosilire cum impetu foras contentum sanguinem viderit.

Simul itaque hæc, & eodem tempore contingunt, tensio cordis, mucronis erectio', pulsus, qui forinsecus sentitur ex allusione eius ad pectus, parietum incrassatio & contenti sanguinis protrusio cum impetu à constrictione ventriculorum.

Hinc contrarium vulgariter receptis opinionibus, apparet, cum eo tempore, quo cor pectus ferit, & pulsus foris sentitur; vna cor distendi secundum ventriculos; & repleri sanguine putetur, quanquam contra rem se habere intelligas, videlicet cor dum contrahitur inaniri. Vndo qui motus vulgo cordis Diastole existimatur, reuera Systole est. Et similiter motus proprius cordis; Diastole non est, sed Systole, neque in Diastole vigoratur cor, sed in Systole, tum enim tenditur, mouetur, vigoratur.

Neque omnino admittendum illud; tametsi diuini Vesalii adducto exemplo confirmatum; De vimineo circulo scilicet ex multis iuncis pyramidatim iunctis, cor secundum fibras rectas tantum moueri; Et sic dum apex ad basin appropinquat, latera in orbem distendi, & cauitates dilatari, & ventriculos cucurbitulæ formam acquirere, & sanguinem introsumere, nam secundum omnem quem habet ductum fibrarum, cor eodem tempore tenditur, constringitur, & potius incrassari, & dilatari parietes, & substantiam, quam ventriculos; & dum tenduntur fibræ à cono ad basim, & cor vna ad basin trahunt, non in orbem latera cordis inclinarent, sed potius contrarium, vti omnis fibra in circulari positione dum contrahitur versus rectitudinem. Et sicut omnes musculorum fibræ, dum contrahuntur & in longitudine abbreuiantur, ita secundum latera distenduntur, & eodem modo quo in musculorum ventribus incrassantur. adde, quod non solum in motu cordis per directionem, & incrassationem parietum contingit ventriculos coarctari, sed vlteriut eo quod fibræ illæ siue lacertuli, in quibus solum fibræ recte (in pariete enim omnes sunt circulares) ab Aristotele Nerui dictæ, quæ vario in ventriculis cordis maiorum animalium, dum vna contrahuntur, admirabili apparatu, omnia interiora latera veluti laqueo inuicem compelluntur, ad contentum sanguinem maiori robore expellendum.

Neque

Neque verum est similiter, quod vulgo creditur, cor vllo suo motu, aut distentione sanguinem in ventriculis attrahere, dum enim mouetur, & tenditur, expellit: dum laxatur, & concidit, recipit sanguinem eo modo, quo postea patebit.

CAPVT III.

Arteriarum motus qualis ex viuorum dissectione.

VLterius in cordis motu obseruanda veniunt hæc, quæ ad arteriarum motus, & pulsationes spectant.

I. Eo tempore quo cordis fit tentio, contractio, percussio pectoris, & omnino Systole, Arteriæ dilatãtur, pulsum edunt, & in sua sunt Diastole: Similiter eo tempore quo dexter ventriculus contrahitur, & protrudit contentum sanguinem, vena arteriosa pulsat, & dilatatur simul cum reliquis arteriis corporis.

II. Quando sinister ventriculus cessat moueri, pulsare, & contrahi: cessat pulsus arteriarũ; imo quando languidius tenditur, pulsus in arteriis vix perceptibilis, & similiter cessante dextro in vena arteriosa.

III. Item secta quauis arteria, vel perforata in ipsa tentione ventriculi sinistri propellitur foras sanguis ex vulnere cum impetu. Similiter secta vena arteriosa eodem tempore, quo dexter ventriculus tenditur, & contrahitur, exinde cum impetu sanguinem prosilire videbis.

Similiter etiam in piscibus secta fistula, quæ è corde in bronchia ducit, quo tempore cor tendi, & contrahi videbis, eo vna etiam sanguinem exinde pertrudi cum impetu.

Similiter denique cum in omni arteriotomia sanguis prosiliendo exeat modo longius modo propius saltum fieri in arteriarum Diastole, & quo tempore cor pectus ferit, comperies: atque hoc nimirum eo tempore quo cor tendi, & contrahi apparet, & in sua esse Systole erectione, vnaque sanguis expellitur eodem motu.

Ex his videtur manifestum contra communia dogmata, quod arteriarum Diastole sit eo tempore, quo cordis Systole: & arterias repleri, & distendi, propter sanguinis à constrictione ventriculorum cordis immissionem, & intrusionem; quin etiam distendi arterias, quia replentur vt vtres, aut vesica; non repleri, quia distenduntur vt folles. Et eadem de causa vniuersi corporis arteriæ pulsant, videlicet, à tensione sinistri cordis ventriculi, sicut vena arteriosa à dextri.

Denique arteriarum pulsum fieri ab impulsu sanguinis è ventriculo sinistro: eodem pacto, quo cum quis in chirothecam inflat, omnes digitos simul, & vna distendi, & pulsum æmulari: etenim secundum cordis tentionem pariter pulsus fiunt maiores, vehementiores, frequentes, celeres, rythmum, & quantitatem, & ordinem seruantes, nec est expectandum, vt propter motum sanguinis tempus inter constrictionem cordis, & arteriarum (præcipue magis distantium) dilationem intercedat, ne fiant simul, cum eodem modo se habet, vt in inflatione chirothecæ, aut vesicæ, quod per plenum, (vt per tympanum, & in longis lignis) ictus, & motus simul sunt in vtroque extremo, & quod Aristoteles: *Palpitat intra venas* (arterias intelligit) *sanguis omnium animalium pulsuque simul vndique mouetur, sic pulsant venæ omnes & simul inuicem, propterea quod pendent omnes à corde; mouet autem semper, quare & illæ semper, & simul inuicem quando mouet.*

3. Anim. cap. 9. De respir. cap. 15.

Notandum cum Galeno, à veteribus Philosophis venas pro arteriis, appellatas fuisse. Accidit aliquando me vidisse, & præ manibus habuisse casum quendam, qui mihi hanc veritatem apertissime confirmabat. Habuit quidam tumorem ingentem pulsantem Aneurisma dictum in dextra parte juguli prope descensum arteriæ subclauiæ in axillas ab ipsius arteriæ exesione prognatum (qui summum in dies incrementum capessebat) & illud propter missionem sanguinis ab arteria, singulis pulsationibus distentis (quod secto post mortem cadauere) deprehensum erat) in illo pulsus eiusdem brachii exilis admodum, eo quod maior sanguinis portio, & influxus in tumorem diuertebatur, & interceptus fuit.

Quare siue per compressionem, siue per infarctum, vel interceptionem vbicunque sanguinis motus per arterias præpeditur, ibi vlteriores arteriæ minus pulsant, cum pulsus arteriarum, nil nisi impulsus sit sanguinis in arterias.

CAPVT IV.

Motus cordis & auricularum qualis ex viuorum dissectione.

PRæter hæc circa motum cordis obseruanda sunt, quæ ad auricularum vsum spectant.

Quod Caspar Bauhinus & Iohannes Riolanus, viri doctissimi, & Anato-

aubin. b.2.c.21. oan.Rio- n. lib. 8. ap.1.

Anatomici peritissimi obseruarũt & admonent, quod si in viua sectione alicuius animalis cordis motum studiose obserues, quatuor motus loco,& tempore distinctos aspicies: quorum duo sunt proprii auricularum, ventriculorum duo. Pace tantorum virorum, quatuor sunt motus, loco, non vero tempore distincti. Simul enim ambæ auriculæ mouent, & simul ambo ventriculi, vt quatuor loco motus distincti sunt duobus tantum temporibus, atque hoc se habet modo.

Duo sunt quasi eodem tempore motus, vnus auricularum, alteri- ptorum ventriculorũ: nec enim simul omnino fiunt: sed præcedit motus auricularum,& subsequitur cordis, & motus ab auriculis incipere, & in ventriculos progredi visus est. cum iam languidiora omnia emoriente corde, & in piscibus, & in frigidioribus sanguineis animalibus inter hos duos motus, tempus aliquod quietis intercedit, vt cor quasi suscitatum motui respondere videtur, aliquando citius, aliquando tardius, & tandem ad mortem inclinans cessat motu suo respondere, & quasi capite duntaxat leuiter annuit,& obscure adeo mouetur, vt potius motus signum præbere pulsanti auriculæ videatur. Sic prius desinit cor pulsare, quam auriculæ, vt auriculæ superuiuere dicantur, & primus omnium desinit pulsare sinister ventriculus, deinde eius auricula, demum dexter ventriculus, vltimo (quod etiam notauit Galen.) reliquis omnibus cessantibus,& mortuis pulsat vsque dextra auricula, vti vltimo in dextra auricula vita remanere videatur. Et dum sensim emoritur cor videre licet, post duas vel tres pulsationes auricularum aliquando quasi expergefactum correspondere,& vnum pulsum lente, & ægrè peragere,& moliri.

Sed & præcipue notandum, quod postquam cessauit cor pulsare adhuc auricula pulsante digito super ventriculum cordis posito, singulæ pulsationes percipiuntur in ventriculis, eodem plane modo, quo ventriculorum pulsationes in arteriis sentiri antea diximus, à sanguinis impulsu nimirum distẽtione facta,& hoc tempore, pulsante solum auricula, si forfice cordis mucronem abscecueris, exinde singulis auriculæ pulsationibus sanguinem effluere conspicies: vt hinc pateat quomodo in ventriculos sanguis ingrediatur, non attractióne, aut distentione cordis, sed ex pulsu auricularum immissus.

Notandum est vbique omnes, quas voco,& in auriculis, & in corde pulsationes, contractiones esse: & plane primo contrahi auriculas videbis,& in consequentia, cor ipsum. Auriculæ enim dum mouentur,& pulsant

pulſant albidiores fiunt, præſertim vbi pauco ſanguine replentur (replentur autem tanquam promptuarium, & lacuna ſanguinis, declinante ſponte ſanguine, & venarum motu compreſſo ad centrum) quin etiam in finibus, & extremitatibus ipſarum hæc albedo à contractione fieri, vel maxime apparet.

In piſcibus, & ranis, & ſimilibus (vnum ventriculum habent cordis & pro auricula veſicam quandam in baſi cordis poſitam refertiſſimam ſanguine) hanc videbis veſicam primo contrahi, & ſubſequi poſtea cordis contractionem apertiſſime.

At vero & quæ his contrario modo ſe habent à me obſeruata aſcribere huc viſum eſt. Cor anguillæ, & quorundam piſcium, & animaliũ etiam exemptum ſine auriculis pulſat: Immo ſi in fruſta diſſecueris partes eius diuiſas ſeparatim ſeſe contrahere, & laxare videbis ita, vt in his poſt ceſſationem motus auricularum cordis corpus pulſum faciat, & palpitet. Sed an hoc proprium viuacioribus animalibus, quorum radicale humidum glutinoſum magis, aut pingue, & lentum eſt, & non ita facile diſſolubile. Quod etiam apparet in carne anguillarum, quæ poſt excoriationem, exenterationem, & in fruſta diſſectionem motum retinet.

In Columba certe experimento facto poſtquam cor deſierat omnino moueri, & nunc etiam auriculæ motum reliquerant per aliquod ſpacium digitum ſaliua madefactum, & calidum cordi ſuperimpoſitũ detinui: Quo fomento quaſi vires, & vitam poſtliminio recuperaſſet, cor, & eius auricula moueri, & ſeſe contrahere, atque laxare, & quaſi ab orco reuocari videbantur.

Sed & præter hæc aliquoties à me obſeruatum fuit, poſtquam cor ipſum, & eius auricula etiam dextra, à pulſatione quaſi mortis articulo quieſcebant; in ipſo ſanguine qui in dextra auricula continetur, obſcurum motum, & inundationem, ac palpitationem quandam manifeſto ſuperfuiſſe, tamdiu ſcilicet, qua calore & ſpiritu imbui videretur.

Tale quiddam euidentiſſime in prima animalis generatione intra ſeptem dies ab incubatione, in ouo Gallinaceo cernitur. Ineſt primum ante omnia gutta ſanguinis, quæ palpitat (quod etiam annotauit Ariſtot.) ex qua incremento facto, & pullo aliqua ex parte formato, fiunt cordis auriculæ, quibus pulſantibus perpetuo ineſt vita: cum poſtea corpus delineari intermiſſis aliquot diebus inceperit, tum etiam cordis corpus procreatur, & per aliquod tempus albidum apparet, & ex-

angue, vt reliquum corpus, nec pulſum edit, nec motum. Quin etiam in fœtu humano vidi, circa principium tertii menſis ſimiliter cor formatum, ſed albidum, & exangue, cuius tamen auriculis ſanguis inerat vberrimus & purpureus. Sed enim in ouo, iam adaucto, & conformato fœtu, ſimul, & cor adaugeri, & ventriculos habere, quibus ſanguinem tunc recipere, & tranſmittere occepit.

Ita vt ſi penitius introſpicere quis velit, non ſolum cor eſſe primum viuens, & vltimum moriens dixerit, ſed auriculas (& quæ in ſerpentibus, piſcibus, & huiuſmodi animalibus pars pro auricula eſt) & prius quam cor ipſum viuere, & poſt etiam emori.

Imo an prius adhuc ipſe ſanguis, vel ſpiritus habeat in ſe obſcuram palpitationem quam poſt mortem retinere mihi viſus eſt: & an cum palpitatione vitam incipere dicamus, dubitare contingit, quandoquidem, & ſperma animalium omnium (vt notauit Ariſt.) & ſpiritus prolificus palpitando exit, velut animal quoddam. Ita Natura in morte quaſi decurſione facta reducem (vt Ariſt.) agat motu retrogrado à calce ad carceres eo vnde proruit ſeſe recipit, & cum animalis generatio ex non animali procedat in animal, tanquam ex non ente in ens iiſdem retro gradibus corruptio ex ente reuoluatur in non ens, vnde quod in animalibus vltimo fit deficit primum & quod primo vltimum.

De motu animaliū. cap. 8.

Obſeruaui quoque in omnibus pene animalibus cor vere ineſſe, & non ſolum (vt Ariſtot. dicit) in maioribus, & ſanguineis, ſed in minoribus, exanguibus, cruſtatis, & teſtaceis quibuſdam, vt lumacibus, cochleis, conchis, aſtacis, gammaris, ſquillis, multiſque aliis; imo veſpis, & crabronibus muſcis (ope perſpicilli ad res minimas diſcernendas) in ſummitate illius particulæ quæ cauda dicitur, & vidi pulſans cor, & aliis videndum exhibui.

In exanguibus vero Cor lente admodum, rariſque ictibus pulſat, atque vt in aliis iam moribundis contingit, & tarde ſeſe contrahit, vt facile in cochleis eſt cernere. Quorum cor deprehendes in fundo illius orificii in latere dextro quod ſe aperire, & claudere euentationis cauſa videtur, & vnde ſaliuam expuit, ſectione facta in ſummitatem iuxta partem iecori analogam.

Sed notandum & hoc, hyeme, & frigidioribus tempeſtatibus exanguia aliqua (qualis eſt Cochlea) nihil pulſans habent, ſed vitam magis plantæ agere videntur, vt etiam reliqua quæ plant-animalia ideo dicuntur.

Notan-

Notandum insuper in omnibus animalibus vbi cor inest, ibi etiam auriculas esse vel auriculis aliquid analogon: Et vbicunque cor duplici ventriculo donatur, ibi duas semper adstare auriculas, non contra: Sed si in ouo pulli conformationem aduertas: Primum inest vt dixi, tantum vesicula, vel auricula, vel gutta sanguinis pulsans, postea incremento facto absoluitur cor. Ita quibusdam animalibus (quasi vlteriorem perfectionem non adipiscentibus) pulsans vesicula quædam instar puncti cuiusdam rubri vel albi, duntaxat inest, quasi principium vitæ: vti apibus, vespis, cochleis, squillis, Gammaris, &c.

Est hic apud nos minima squilla (quæ Anglicè dicitur a Shrimp, Belgice een Herneel) in mari, & in Thamesi capi solita, cuius corpus omnino pellucidum est: Eam aquæ impositam sæpius præbui spectandam amicissimis quibusdam meis, vt cordis illius animalculi motus liquidissime perspiceremus, dum exteriores illius corporis partes visui nihil officerent, quo minus cordis palpitationem quasi per fenestram intueremur.

In ovo Gallinaceo post quatuor, vel quinque dies ab incubatione, primum rudimentum pulli instar nubeculæ videndum exhibui, nimirum ouo cui cortex adimebatur, in aquam limpidam, tepidamque immisso, in cuius nubeculæ medio punctum sanguineum palpitans tam exiguum erat, vt in contractione dispareret, & visum aufugeret in laxatione instar summitatis acus appareret rubicundum: Ita vt inter ipsum videri, & non videri quasi inter esse & non esse, palpitationem & vitæ principium ageret.

CAPVT V.

Cordis motus actio, & functio.

EGo vero ex his tandem, & huiusmodi obseruationibus repertum iri confido, motum cordis ad hunc modum fieri.

Primum sese contrahit auricula. & in illa contractione sanguinem contentum (quo abundat tanquam venarum caput, & sanguinis promptuarium, & cisterna) in ventriculum cordis coniicit, quo repleto cor sese erigit, continuo omnes neruos tendit, contrahit ventriculos, & pulsum facit, quo pulsu immissum ab auricula sanguinem continenter protrudit in arterias, dexter ventriculus in pulmones per vas illud,

quod vena arterioſa nominatur,ſed re vera,&conſtitutione,& officio, & in omnibus arteria eſt:ſiniſter ventriculus in aortam, & per arterias in vniuerſum co pus.

Iſti duo motus,auricularum vnus, alter ventriculorum ita per conſecutionem fiunt, ſeruata quaſi harmonia & Rhytmo, vt ambo ſimul fiant, vnicus tantum motus appareat, præſertim in calidioribus animalibus, dum illa celeri agitantur motu. Nec alia ratione id fit quam cum in machinis, vna rota aliam mouente, omnes ſimul mouere videantur, & in mechanico il'o artificio, quod ſelopetis adaptant, vbi compreſſione alicuius ligulæ, cadit ſilex, percutit chalybem, & propellit, ignis elicitur, qui in puluerem cadit, ignitur puluis,interius prorepit, diſploditur, euolat globulus, metam penetrat, & omnes iſti motus propter celeritatem quaſi in nictu oculi ſimul fieri apparent. Sic etiam in deglutitione radicis, linguæ eleuatione, & oris compreſſione,cibus vel potus in fauces deturbatur,larinx à muſculis ſuis, & epiglottide clauditur, eleuatur, & aperitur, ſummitas gulæ à muſculis ſuis,haud aliter quam ſaccus ad implendum attollitur, & ad recipiendum dilatatur,& cibum,vel potum acceptum tranſuerſis muſculis deprimit, & longioribus attrahit: Et tamen omnes iſti motus à diuerſis, & contradiſtinctis organis facti, cum harmonia, & ordine, dum fiunt,vnum efficere motum videntur,& actionem vnam,quam deglutitionem vocamus.

Sic contingit plane in motione, & actione Cordis, quæ deglutitio quædam eſt,& transfuſio ſanguinis ę venis in arterias: Et ſi quis (dum hæc habuerit in animo) cordis motum diligenter in viua diſſectione animaduerterit,videbit,non ſolum,quod dixi,cor ſeſe erigere, & motum vnum fieri cum auriculis continuum, ſed inundationem quandā, & lateralem inclinationem obſcuram ſecundum ductum ventriculi dextri,& quaſi ſeſe leuiter contorquere,& hoc opus peragere: Et quémadmodum cernere licet,cum equus potat,& aquam deglutit, ſingulis gulæ tractibus abſorberi aquam,& in ventriculum demitti, qui motus ſonitum facit & pulſum quendam & auſcultantibus,& tāgentibus exhibet,ita dum iſtis cordis motibus fit portionis ſanguinis è venis in arterias traductio,pulſum fieri,& exaudiri in pectore contingit.

Motus itaq; cordis omnino ad hunc ſe habet modum, & vna actio cordis eſt ipſa ſanguinis transfuſio,& in extrema vſq;,mediantibus arteriis propulſio, vt pulſum; quem nos ſentimus in arteriis, nil niſi ſanguinis à corde impulſus ſit.

An vero

An vero cor ſanguini præter tranſpoſitionem, & motum localem, & diſtributionem aliquid aliud addat, ſiue calorem, ſiue ſpiritum, ſiue perfectionem, poſterius inquirendum, & ex aliis obſeruationibus colligendum: Hoc in præſentia ſufficiat ſatis oſtenſum eſſe in pulſu cordis ſanguinem transfundi, & deduci è venis in arterias per cordis ventriculos, & diſtribui in vniuerſum corpus.

Sed & hoc omnes aliquo modo concedunt, & ex cordis fabrica, & valuularum artificio, poſitione, & vſu colligunt. Verum tanquam in loco obſcuro titubantes cœcutire videntur, & varia, ſubcontraria, & non cohęrentia componunt, & ex coniectura plurima pronunciant, vt ante demonſtratum eſt.

Cauſa maxima hac in parte hæſitandi, & errandi vna fuiſſe mihi videtur, cordis cum pulmone in homine contextus: cum venam ibi arterioſam in pulmones obliterari, & ſimiliter arteriam venoſam conſpexiſſet, vnde aut quomodo dexter ventriculus in corpus diſtribueret ſanguinem: aut ſiniſter è vena caua exhauriret, obſcurum admodum illis erat; hoc atteſtantur Galeni verba (dum contra Eraſiſtratum de venarum origine & vſu, & ſanguinis coctione, inuehitur) *reſpondebitis* (inquit) *ita eſſe effectum, vt in iecore ſanguis præparetur, atque inde in cor deferatur, ibi poſtea reliquam propriæ formæ perfectionem abſolutam accepturus. Quod profecto ratione vacare non videtur: Nullum enim perfectum & magnum opus repente vna aggreßione fieri, totamque ſuam expolitionem ab vno inſtrumento acquirere poteſt. Quod ſi ita eſt, oſtendite nobis vas aliud, quod è corde ſanguinem abſolute perfectum educat, atque ipſum vt arteria ſpiritum, in totum corpus diſpenſet;* Ecce opinionem rationabilem non approbaſſe, & reliquiſſe Galenum (quia præterquam quod viam tranſitus non videbat) vas reperire non poterat, quod in totum corpus è Corde ſanguinem diſpenſet.

Galen. de placitis Hippoc. & Plat. 6.

Si quis vero ibidem pro Eraſiſtrato, vel pro illa, & nunc noſtra opinione (ipſius confeſſione Galeni) alias rationi conſentanea inſtaret, & arteriam magnam ſanguinem è corde in vniuerſum corpus diſpenſantem digito commonſtraſſet; Quid diuinus ille vir ingenioſiſſimus & doctiſſimus reſponderet, miror. Si arteriam ſpiritus diſpenſare & non ſanguinem diceret; profecto Eraſiſtratum refelleret ſatis (qui in arteriis ſpiritus duntaxat contineri arbitrabatur) ſed ſibi ipſi contradiceret interea & id eſſe turpiter negaret, quod

libro

lib optoprio acriter esse contendit, contra eundem Eristratum: & multis, & validis argumentis comprobat, & experimentis demonstrat, quod sanguis contineatur in arteriis natura, & non spiritus.

„ *Sin vero* diuinus vir (vti facit eodem loco sæpius) *concederet, omnes* „ *arterias corporis à magna arteria oriri, & hanc à corde: quin etiam in ipsis o-* „ *mnibus sanguinem natura contineri, & deferri, & valuulas illas tres sigmoides* „ *orificio aortæ positas, regressum sanguinis in cor prohibere professus, & quod hæc* „ *Natura nequaquam præstantissimo visceri constituisset, nisi maximum aliquod* „ *ministerium illæ fuissent exhibituræ.* St (inquam) hæc omnia, & his ipsissimis verbis concederet Pater Medicorum, (vti facit *recitato libro.*)

Quomodo negare possit arteriam magnam istiusmodi vas esse quod sanguinem (iam absolutam suam perfectionem adeptum) è corde in vniuersum corpus dispenset, non video. An adhuc forsan hæsitaret, vt omnes in hunc vsque diem post ipsum, quod propter contextum, vt dixi cordis cum pulmone, non videat vias, per quas sanguis è venis in arterias transferri possit.

Quod dubium etiam anatomicos (dum semper in dissectionibus inueniunt arteriam venosam, & sinistrum ventriculum cordis repletos sanguine, eoque crasso, grumescente, atro) non mediocriter perturbat cum sanguinem è dextro ventriculo in sinistrum per septum cordis transudare coacti sint affirmare. Sed hanc viam antea refutaui: Iam ideo via paranda est, & aperienda, qua inuenta, nunc nulla esset difficultas, quæ quempiam (credo) inhiberet, quo minus quæ ante proposui (de pulsu cordis, & arteriarum, de transfusione sanguinis è venis in arterias, & de dispensatione in vniuersum corpus per arterias) concedere, & agnoscere facile possit.

CAPVT VI.

Quibus viis sanguis, è vena Caua in arterias, vel e dextro ventriculo cordis in sinistrum deferatur.

CVm errandi occasionem præbuisse probabile sit, quam in homine vident (vt dixi) cordis cum pulmone connexionem: In hoc peccant, qui dum de partibus animalium (vti vulgo omnes Anatomici faciunt) pronunciare, & demonstrare, aut cognoscere volunt, vnum tãtum hominem, eumque mortuum introspiciunt, & sic tanquam, qui

vna

vna reipub. forma perſpecta diſciplinam politicam componere, aut vnius agri naturam cognoſcentes, agriculturam ſe ſcire opinantur: Nihilo plus agunt, quam ſi ex vna particulari propoſitione, de vniuerſali Syllogizare darent operam.

Veruntamen, ſi in diſſectione animalium æque verſati eſſent, ac in humani cadaueris anatome exercitati: Res hæc in dubio, quæ omnes perplexos retinet, palam abſque omni difficultate mea ſententia eluceſceret.

In piſcibus, in quibus vnus tantum ventriculus cordis (vt non habentibus pulmones) res primum ſatis manifeſta eſt, veſicam enim ſanguinis in baſi Cordis poſitam, auriculæ nimirum analogon, ſanguinem in cor immittere, quem cor denuo per fiſtulam ſiue arteriam, vel arteriæ analogon, aperte tranſmittere, tum viſu, tum ſecta arteria (exindo ſanguine ſingula pulſatione cordis proſiliente) oculis palam confirmari poſſe conſtat.

Idem etiam deinde in omnibus animalibus, in quibus vnus duntaxat ventriculus, vel quaſi vnus, non difficile eſt cernere, vt in bufone, rana, ſerpentibus, lacertis, quæ etſi pulmones aliquo modo habere dicuntur, vt qui vocem habent (de quorum pulmonum artificio admirando, & de cæteris eiuſmodi, permultas apud me obſeruationes habeo quæ non ſunt huius loci) tamen ex autopſia eodem modo in illis è venis in arterias ſanguinem pulſu cordis traductum eſſe palam eſt, & via patens aperta, manifeſta, nulla difficultas, nullus hæſitandi locus: In his enim perinde ſe res habet atque in homine, ſi ſeptum cordis perforatum, aut ademptum eſſet, aut vnus ex vtriſque fieret ventriculus, quo facto, nemo credo dubitaſſet, qua via ſanguis è venis in arterias tranſire potuiſſet.

Cum vero maior numerus animalium non habentium pulmones ſit, quam habentium, & ſimiliter maior numerus ſit, vnum tantum ventriculum cordis, quam habentium duos, procliue eſt ſtatuere in animalibus ἐπὶ τὸ πολὺ vt plurimum, & in vniuerſum, ſanguinem aperta via è venis in arterias per cordis ſinum tranſmitti.

Conſideraui autem mecum, quod etiam in embryonum eorum quę pulmones habent, idem apertiſſime conſtat.

In fœtu vaſa cordis quatuor (videlicet vena caua, vena arterioſa, arteria venalis, & Aorta, ſiue arteria magna) alio modo vniuntur, quàm in adulto, quod omnes Anatomici norunt ſatis.

Primus contactus, & vnio venæ cauæ cum arteria venosa (quæ fit priusquam caua in dextrum ventriculum cordis se aperiat, aut venam coronalem emittat, paululum supra egressum ab hepate) Anastomosim lateralem exhibet, hoc est, foramen amplum patens, ouali figura. pertusum è caua in arteriam illam peruium, ita vt (tanquam per vnum vas) per illud foramen sanguis de vena caua in arteriam venosam, & auriculam cordis sinistram vsque in ventriculum sinistrum liberrime, & copiosissime dimanare possit. Insuper in illo foramine ouali è regione, quæ arteriam venosam respicit, operculi instar membrana tenuis dura est, foramine maior, quæ postea in adultis, operiens hoc foramen, & coalescens vndique istud foramen omnino obstruit, & prope obliterat: Hæc inquam membrana sic constituta est, vt dum laxe in se concidit, facile ad pulmones, & cor via resupinetur, & sanguini à caua affluenti cedat quidem, at ne rursus in cauam refluat, impediat, vt liceat existimare in embryone sanguinem continuo debere per hoc foramen transire de vena caua in arteriam venosam, & inde in auriculam sinistram cordis, postquam ingressum fuerit, remeare nunquam posse.

Altera vnio est venæ arteriosæ (quæ fit postquam vena illa, è dextro ventriculo egressa in duos diuiditur ramos) est tanquam duobus dictis, tertius truncus, & quasi canalis arteriosus; ab hinc in arteriam magnam oblique ductus, & perforatus: vt in dissectione Embryonum quasi duæ aortæ, vel radices arterię magnæ è corde exorientes duæ appareant.

Canalis hic in adultis similiter sensim attenuatur, tabescit, & penitus tandem vt vena vmbilicalis exiccatur, & aboletur.

Iste canalis arteriosus nullam membranam in se habet, sanguinis motum hinc, vel illinc impedientem. Sunt enim in orificio illius venæ arteriosæ (cuius iste canalis, vti dixi, propago est) valuulæ sigmoides tres quæ intus foras spectant, & sanguini è dextro ventriculo hac via in magnam arteriam fluenti cedunt facile, remeare vero contra ab arteria quidquam, aut à pulmonibus in dextrum ventriculum ad amussim clausum omnino impediunt. Vt hic etiam arbitrari consentaneum sit in Embryone, dum cor sese contrahit continuo sanguinem è dextro ventriculo hac via in arteriam magnam inuehi.

Quod vulgo dicitur, has duas vniones tam magnas, patentes, & apertas,

apertas, nutriendorum pulmonum cauſa, factas fuiſſe tantum: & in adultis (cum iam pulmones propter ipſorum calorem, & motum copioſius nutrimentum deſiderarent) aboleri, & conſolidari; Commentum improbabile eſt, & male cohærens. Et ſimiliter quod dicunt cor in embryone feriari, & nihil agere, nec mouere, vnde Natura hos tranſitus facere, alendorum pulmonum cauſa coacta erat, falſum eſt: cum in ouo cui gallina incubuit, & in Embryonibus recenter ex vtero erectis autopſia patet, tum cor mouere ſicut in adultis tum naturam nulla tali neceſſitate vrgeri: Cui motui non ſolum hi oculi ſæpe teſtes, ſed & Ariſtoteles atteſtatur ipſe: *Pulſus* (inquit) *per initia ſtatim in conſtitutione cordis emergit, & quod in ſectione viuorum, & pulli formatione ex ouo deprehenditur.* Quin & obſeruàmus has vias (tam in hominum genere, quam in cæteris animalibus) non ſolum apertas, & patentes eſſe vſque ad tempus partus (vt annotarunt Anatomici) ſed etiam permultos poſt menſes, imo in aliquibus per aliquot annos, ne dicam toto vitæ curriculo, veluti in anſere, buccagine, & auibus plurimis, & animalibus præſertim in minoribus. Quæ res impoſuit forſan Botallo ſe nouum tranſitum ſanguini de vena caua in ſiniſtrum ventriculum cordis inueniſſe, & fateor, me quoque cum in mure maiori iam adulto hoc primum ipſe reperi, tale quid ſtatim exiſtimaſſe.

Lib. ſpir

Ex quibus intelligitur in Embryone humano, quin, & in aliis, in quibus iſtæ vniones non abolentur, idem ipſum accidere, vt cor ſuo motu, per patentiſſimas vias ſanguinem de vena caua in arteriam magnam apertiſſime traducat, per vtriuſque ventriculi ductum. Dexter ſiquidem ſanguinem ab auricula recipiens, inde per venam arterioſam, & propaginem ſuam (canalem arterioſam dictam) in magnam arteriam propellit. Siniſter ſimiliter eodem tempore mediante auriculæ motu recipit ſanguinem (in illam ſiniſtram auriculam diductum ſcilicet per foramen ouale è vena caua) & tentione ſua, & conſtrictione per radicem aortæ in magnam itidem arteriam ſimul impellit.

Ita in Embryonibus dum interea pulmones otiantur, & nullam actionem aut motum habent, quaſi nulli forent, natura duobus ventriculis cordis quaſi vno vtitur, ad ſanguinem tranſmittendum. Et ſimilis eſt conditio Embryonum pulmones habentium, dum adhuc pulmonibus non vtuntur, ac eſt eorum animalium, qui pulmones non habent.

Itaque tam clare in his etiam elucescit veritas, quod cor suo pulsu sanguinem è vena caua in arteriam magnam traducat, & transfundat, perque tam patentes, & apertas vias, ac si in homine, quod dixi ambo ventriculi (eorum septo adempto) adinuicem peruii essent facti. Cum itaque maiori ex parte animalibus, & omnibus quodam tempore, patentissimæ istæ extent viæ, quæ transmissioni sanguinis per cor inseruiunt: restat vt illud perquiramus. Aut cur in quibusdam animalibus (vt in homine) iisque calidioribus, & adultis per pulmonum substantiam illud fieri non existimemus, quod in embryone natura per eas vias illo tempore quo pulmonum nullus erat vsus antea effecit, quas ob defectum transitus per pulmones coacta videbatur facere. Aut, cur melius sit (natura enim semper quod est melius facit) in adolescentibus sanguinis transitui naturam omnino occlusisse, vias patentes illas quibus ante in embryone & fœtu via fuerat, & omnibus aliis animalibus vtitur, nec alias vllas pro illo sanguinis transitu aperuisse, sed sic omnino impedire.

Ita iam eo res cessit, vt iis qui in homine quærunt vias, quomodo sanguis è vena caua in sinistrum vẽtriculum, & arteriam venosam permeat. Magis operæ pretium esset, & recte magis factum videretur, si ex dissectione animalium veritatem inuestigare vellent, vt causam inquirant, cur in maioribus, & perfectioribus animalibus, iisque adultis natura sanguinem transcolari per pulmonum Parenchyma potius vellet, quam vt in cæteris omnibus per patentissimas vias (cum nullam aliam viam, & transitum excogitari posse intelligerent, siue hoc sit quod maiora, & perfectiora animalia sint calidiora, & cum sint adulta, eorum calor magis (vt ita dicam) igniatur & vt suffocetur sit procliuis: Ideo tranare, & traiici per pulmones, vt inspirato aere contemperetur, & ab ebullitione, & suffocatione vindicetur, siue quid aliud tale. Sed hæc determinare, & rationem omnem reddere, nihil aliud agere est, quam propter quid pulmones facti sunt, speculari. Atque de his horumque vsu, & motu, & de euentatione omni, & aeris necessitate, & vsu, & cæteris huiusmodi: Et de variis organis, & differentibus huius causa in animalibus factis: tametsi multa quam plurimis obseruationibus à me deprehensa sint: Tamen, ne nimium à proposito de motu, & vsu cordis hoc loco aberrando, aliud agere, & stationem relinquere, rem interturbare, & subterfugere videar, hæc proprio tractatu conuenientius exponenda relinquam. Et quæ restant vt ad propositum scopum reuertar confirmare pergam.

In.

In perfectioribus nimirum & calidioribus animalibus, iisque adultis (vt in homine) sanguinem de dextro ventriculo cordis per venam arteriosam in pulmones, & inde per arteriam venosam in sinistram auriculam, & subinde in ventriculum cord s sinistrum permeare contendo: Et primum posse hoc fieri, deinde ita factum esse.

CAPVT VII.

Sanguinem de dextro ventriculo cordis per pulmonum parenchyma permeare in arteriam venosam, & sinistrum ventriculum.

Fieri autem hoc posse, & nihil esse, quo minus fiat, satis constat, cum & quomodo aqua per terræ substantiam permeans, riuulos, & fontes procreet, consideremus, aut quomodo per cutem sudores: per parenchyma renum, vrina fluat, speculamur. Animaduertendum est in iis, qui Aquis Spadensibus vtuntur: vel de la Madonna (vt aiunt) in agro Patauino, vel aliis acidulis, aut vitriolatis, vel qui ad congios ingurgitant potum, vt vna aut altera hora per vesicam emingant totum. Debet ista copia aliquantulum in concoctione immorari: debet per iecur (vt singulis diebus bis ingesti alimenti succum omnes confitentur facere) debet per venas, per renum parenchyma, per vretres in vesicam profluere.

Quos itaque audio negantes posse sanguinem, imo totam massam sanguineam, per pulmonum substantiam, æque ac succus alimentalis per iecur permeare, tanquam impossibile, & nullo modo credibile existimandum? Quod genus hominum (cum Poeta loquor) vbi volunt concedunt facile posse: vbi nolunt nullo modo: hic vbi opus est verentur, vbi nihilo opus, ibi non verentur affirmare.

Iecoris Parenchyma densias multo est, & similiter renum: pulmonum rarioris multo texturæ. Et si renibus & iecori conferatur spongiosæ.

In iecore nullum impellens, nulla vis cogens; in pulmone ex pulsu dextri ventriculi cordis impingitur sanguis, cuius impulsu distendi vasa, & porositates pulmonum necesse est. Præterea pulmones in respirando eleuantur, & concidunt, quo motu necesse est, vt porositates & vasa aperiantur, & claudantur, vt in spongiis contingit, & in omnibus par-

Gal. de vs. part.

 bus par-

bus particulis habentibus constitutionem spongiosam, quando constringuntur, & rursus dilatantur. Contra jecur quiescit, nec ita dilatari, & constringi visum est.

Denique si per jecur totum ingestorum succum in venam cauam, tam in homine, quam in boue, vel in maximis animalibus, nemo est; qui non asserit pertransire posse. Et hoc, eo quod pertransiisse aliqua nutrimentum, & permeasse in venas sit necesse (si fiat nutritio) & nulla alia extet via, ac proinde hoc affirmare coacti sint: Cur non iisdem argumentis de transitu sanguinis in adultis his; per pulmones fidem similem habent, & cum Columbo peritissimo, doctissimoque Anatomico idem assererent, & crederent, ex amplitudine, & fabrica vasorum pulmonum, & eo, quod arteria venosa, & similiter ventriculus, repleti sint semper sanguine, quem è venis huc venisse necesse est, & nulla alia, quam per pulmones semita, vt & ille, & nos ex ante dictis, & autopsia, aliisque argumentis palam esse existimemus.

Sed quando aliqui sunt, qui nil nisi adductis authoritatibus admittunt; iidem ex ipsius etiam Galeni verbis hanc veritatem confirmari posse sciant; scilicet non solum posse sanguinem, è vena arteriosa in arteriam venosam, & inde in sinistrum ventriculum cordis, & postea in arterias transmitti: sed ex continuo pulsu cordis, & pulmonum motu inter respirandum, hoc fieri.

Sunt in orificio venæ arteriosæ, valuulæ tres sigmoides, siue semilunares, quæ omnino sanguinem in illam venam arteriosam immissum non sinunt remeare in cor.

Id omnes norunt scilicet harum valuularum necessitatem & vsum, ,, Galenus his verbis explicans, *In toto est* (inquit) *mutua Anastomosis, at-* ,, *que osculorum apertio arteriis simul cum venis, transumuntque ex sese pariter* ,, *sanguinem, & spiritum per inuisibiles quasdam atque angustas plane vias.* ,, *Quod si os ipsum venæ arteriosæ itidem semper patuisset, nullamque natura in-* ,, *uenisset machinam, quæ claudere ipsum cum est tempestiuum, ac rursus ape-* ,, *rire queat. Fieri nunquam potuisset, vt per inuisibilia, atque exigua osilla,* ,, *sanguis (contracto thorace) in arterias transumeretur: Neque enim simi-* ,, *liter omnis ex quouis attrahitur, neque emittitur. Sed quemadmodum quod* ,, *leue est facilius eo quod grauius dilatatis instrumentis attrahitur, iisdem au-* ,, *tem contractis exprimitur: Ita & per latam viam celerius aliquid quam per* ,, *angustam trahitur, ac rursus emittitur. Cum autem thorax contrahitur, pul-*

Galen. de vsu part. l.6.c.10.

sæ atque

sæ atque intro compressæ vndique fortiter, quæ in pulmone sunt venosæ arteriæ, "
expriment quidem quam celerrime, qui in seipsis est; spiritus; transumunt au- "
tem per subtilia illa oscilla sanguinis portionem aliquam, quod nunquam acci- "
disset profecto, si sanguis per maximum os (cuiusmodi est vena arteriosa ad cor) "
retro remeare potuisset: Nunc vero reditu per os magnum intercluso, dum com- "
primitur vndique, destillat quidpiam in arterias per exigua illa orificia: & pau- "
lo post sequente Capitulo. *Quanto thorax contendit vehementius san-* "
guinem elidens, tanto membranæ, (videlicet valuulæ sigmoides) exactius os ipsum "
occludunt: & nihil remeare sinunt: quod & eodem Capitulo decimo "
paulo ante. *Nisi valuulæ essent, triplex sequeretur incommodum, vt san-* "
guis ipse frustra longum hoc curriculum subinde emetiatur. In Diastolis quidem "
pulmonis adfluens, & quæ in ipso sunt, venas omnes refarciens, in Systolis ve- "
ro, quasi æstus quidam maritimus, instar Euripi motum identidem, huc "
atque illuc reciprocum, qui haudquaquam sanguini conueniat. At hoc vi- "
deri posit exiguum. Quod vero interim ipsius quoque respirationis vtilita- "
tem labefactet, id non amplius pro paruo est habendum, &c. (Et paulo "
post.) *Atque etiam tertium secutum fuisset incommodum, haudquaquam* "
contemnendum, cum sanguis retro in expirationibus remigrasset, nisi opifex "
noster membranarum Epiphysin fuisset fabricatus, vnde concludit Cap. "
vndecimo. *Communis autem ipsorum omnium, videlicet valuularum est* "
vsus, vt materias retro remigrare prohibeant, vtrarumque vero proprius, e- "
ducentium quidem è corde materias, ne amplius ad ipsum remeent; inducentium "
vero, ne amplius ex ipso effluant: Non enim volebat natura vano labore cor fati- "
gari, neque in eam partem aliquando emittere, vnde trahere præstiterat, neque "
rursus ex illa identidem ducere, ad quam mittere erat necesse. Proinde cum sint "
quatuor omnino orificia, bina in vtroq; ventriculo, alterum quidem inducit, al- "
terum vero educit.

Et paullo post: *Porro cum vas alterum quod tunica simplici constat in cor* "
infigatur, alterum quod duplice ex ipso producatur communem vtrique locum, "
[*videlicet ventriculum dextrum:* Ita Galenus intelligit, & ego eadem ratio- "
ne similiter sinistrum ventriculum cordis] *quasi lacunam quandam pa-* "
rari necesse fuit, ad quam pertinentibus vtrisque per alterum quidem trahatur "
sanguis per reliquum vero emittatur.

Quod argumentum Galenus pro transitu sanguinis per dextrum ventriculum de vena caua in pulmones adducit, eodem nobis, rectius pro transitu sanguinis de venis per cor in arterias mutatis tantum terminis vti liceat. Ex Galeni igitur viri diuini patris Medico-

Medicorum locis & verbis clare apparet, & sanguinem per pulmones de vena arteriosa, in arteriæ venosæ ramulos permeare, tum propter pulsum cordis, tum propter pulmonum & thoracis motum. Quinetiam quod cor continue in ventriculos quasi lacunam, recipere & emittere sanguinem, & huius rei causa valuularum genera quatuor, duo inductioni, emissioni sanguinis duo inseruire; ne aut sanguis Euripi in morem inconuenienter agitetur, huc, illuc, aut retro remearet, vnde trahere præstiterat, & ex illa reflueret parte, ad quam mittere erat necesse. Et sic cor vano labore fatigaretur, & pulmonum respiratio præpediretur, Denique clare apparet assertio nostra, continue, & continenter sanguinem per pulmonum porositates permeare de dextro in ventriculum sinistrum, de vena caua in arteriam magnam: Nam cum continuo de dextro ventriculo immittatur sanguis in pulmones per venam arteriosam, & similiter continue è pulmonibus in sinistrum attrahitur (quod ex dictis, & valuularum positione patet) quin pertranseat continue fieri non potest.

Vide Hofmanni doctissimi Commentarium supra Galeni lib. 6. de vsu part. Quem librum postquam hæc à me scripta essent vidi.

Et itidem cum semper & continue ingrediatur sanguis in cordis ventriculum dextrum, & egrediatur continue è sinistro (quod similiter, & ratione & sensu patet) quin continuo pertranseat sanguis de vena caua in Aortam impossibile est.

Illud igitur quod in animalibus maiori ex parte, & plane omnibus donec adolescant, per patentissimas fieri vias, ex dissectione manifestum est, in adultis his per pulmonum cæcas porositates, & vasorum eius oscilla, tam ex Galeni verbis, quam ex ante dictis illud inquam fieri æque manifestum est. Vnde apparet quod quanquam vnus ventriculus cordis videlicet sinister sufficiens esset sanguinis dispensationi per corpus, & eductioni è vena caua, quemadmodum etiam fit in omnibus quæ pulmonibus carent, natura tamen cum voluerit sanguinem ipsum per pulmones transcolari, dextrum ventriculum superaddere coacta fuit, cuius pulsu per ipsos pulmones è vena caua in sinistri ventriculi locum sanguis compelleretur. Et hoc modo dextrum ventriculum pulmonum causa, & ob translationem sanguinis, non ob nutritionem duntaxat dicendum: Quandoquidem tanto prouentu annonæ, atque compulsu subministrato, & tanto puriori, & spirituosiori (vtpote immediate à ventriculis cordis subuecto) indigere alimento pulmones magis, quam aut cerebri purissima substantia, aut oculorum splendidissima, & diuina constitutio, aut ipsius cordis caro, (quæ rectius per arteriam coronalē nutritur) inconueniens omnino est existimare. CA-

CAPVT VIII.

De copia sanguinis transeuntis per cor è venis in arterias, & de circulari motu sanguinis.

HVc vſque de transfuſione ſanguinis è venis in arterias, & de viis, per quas pertranſeat, & quomodo ex pulſu cordis, tranſmittat? diſpenſet? de quibus, forſan ſunt aliqui, qui, antea aut Galeni authoritate, aut Columbi, aliorumue rationibus adductis, aſſentiri ſe dicant mihi; nunc vero, de copia & prouentu iſtius pertranſeuntis ſanguinis, quæ reſtant, (licet valde digna conſideratu) cum dixero; adeo noua ſunt, & inaudita, vt non ſolum ex inuidia quorundam, metuam malum mihi, ſed verear, ne habeam inimicos omnes homines tantum conſuetudo, aut ſemel imbibita doctrina, altiſque defixa radicibus, quaſi altera natura, apud omnes valet, & antiquitatis veneranda ſuſpicio cogit. Vtcumque iam iacta eſt alea, ſpes mea in amore veritatis, & doctorum animorum candore: Sane cum copia quanta fuerat, tam ex viuorum, experimenti cauſa, diſſectione, & arteriarum apertione, diſquiſitione multimoda; tum ex ventriculorum cordis, & vaſorum ingredientium & egredientium Symmetria, & magnitudine, (cum natura nihil faciẽs fruſtra, tantam magnitudinem, proportionabiliter his vaſibus fruſtra non tribuerit) tum ex concinno & diligenti valuularum & fibrarum artificio, reliquaque cordis fabrica, tum ex aliis multis ſæpius mecum & ſerio conſideraſſem, & animo diutius euoluiſſem: quanta ſcilicet eſſet copia tranſmiſſi ſanguinis, quam breui tempore ea tráſmiſſio fieret, nec ſuppeditare ingeſti aliméti ſuccum potuiſſe animaduerterim; quin venas inanitas, omnino exhauſtas, & arterias, ex altera parte, nimia ſanguinis intruſione, diſruptas, haberemus, niſi ſanguis aliquo ex arteriis denuo in venas remearet, & ad cordis dextrum ventriculum regrederetur.

Cœpi egomet mecum cogitare, an motionem quandam quaſi in circulo haberet, quam poſtea veram eſſe reperi, & ſanguinem è corde per arterias in habitum corporis, & omnes partes protrudi, & impelli, à ſiniſtri cordis ventriculi pulſu, quemadmodum in pulmones per venam arterioſam à dextris; & ruſus per venas in venam cauam, & vſque ad auriculam dextram remeari, quemadmodum ex pulmonibus

per arteriam dictam venosam, ad sinistrum ventriculum vt ante dictum est.

Quem motum circularem, eo pacto nominare liceat, quo Aristoteles aerem & pluuiam circularẽ superiorũ motum æmulatus est. Terra enim madida à sole calefacta euaporat, vapores sursum elati condensant, condensati in pluuias rursum descendunt, terram madefaciunt & hoc pacto fiunt hic generationes & similiter tempestatum & meteororum ortus, a solis circulari motu, accessu, & recessu.

Sic verisimiliter cõtingat in corpore, motu sanguinis, partes omnes sanguine calidiori perfecto, vaporoso, spirituoso, (& vt ita dicam) alimentatiuo, nutriri, foueri, vegetari: Contra in partibus sanguinem refrigerari, coagulari, & quasi effatum reddi, vnde ad principium, videlicet, Cor; tanquam ad fontem siue ad lares corporis, perfectionis recuperandæ causa, reuertitur: ibi calore naturali, potenti, feruido, tanquam vitæ thesauro, denuo colliquatur, spiritibus, & (vt ita dicam) balsamo prægnans, inde rursus dispensatur, & hæc omnia à motu & pulsu cordis dependere.

Ita cor principium vitæ & sol Microcosmi (vt proportionabiliter sol Cor mundi appellari meretur) cuius virtute, & pulsus sanguis mouetur, perficitur, vegetatur, & à corruptione & grumefactione vindicatur: suumque officium nutriendo, fouendo, vegetando, toti corpori præstat Lar iste familiaris, fundamentum vitæ author omnium; sed de his conuenientius, cum de huiusmodi motus causa finali speculabimur.

Hinc cum venæ sint viæ quædam, & vasa deferentia sanguinem; duplex est genus ipsarum, caua, & Aorta, non ratione lateris (vt Aristoteles) sed officio; & non (vt vulgo constitutione (cum in multis animalibus (vt dixi) in tunicæ crassitie, vena ab arteris non differat) sed munere & vsu distincta, vena & arteria ambæ à veteribus venæ non immerito dictæ (vt Galenus annotauit) eo quod hæc, videlicet arteria, vas est differens sanguinem, è corde in habitum corporis; illa sanguinem ab habitu rursus in cor; hæc via à corde, ad cor vsque illa; illa continet sanguinem crudiorem, effœtum nutritioni iam redditum inidoneum, hæc coctum, perfectum, alimentiuum.

CAPVT

CAPVT IX.

Esse sanguinis circuitum ex primo supposito confirmato.

SEd ne verba dare nos dicat quispiam, & assertiones speciosas tantum facere sine fundamento, & non iusta de causa innouare: tria cõfirmanda veniunt, quibus positis, necessario hanc sequi veritatem, & rem palam esse arbitror.

Primum continue & continenter, sanguinem è vena caua in arterias, in tanta copia, transmitti, pulsu cordis, vt ab assumptis suppeditari non possit, & adeo vt tota massa breui tempore illinc pertranseat.

Secundum continue æquabiliter & continẽter sanguinem in quodcunque membrum & partem pulsu arteriarum impelli, & ingredi, maiori copia multo, quam nutritioni sufficiens sit, vel tota massa suppeditari possit.

Et similiter tertio ab vnoquoque membro, ipsas venas, hunc sanguinem perpetuo retroducere ad cordis locum.

His positis sanguinem circumire, reuolui, propelli & remeare, à corde in extremitates, & inde in cor rursus, & sic quasi circularem motum peragere, manifestum puto fore.

Supponamus (vel cogitatione, vel experimento) quantum sanguinis, sinister ventriculus in dilatatione (quum repletus sit) contineat siue ℥ij. siue ℥iij. siue ℥j. ʃ. ego in mortuo reperi vltra ℥ij.

Supponamus similiter, quanto minus in ipsa contractione, vel quãtum sese contrahat cor, & quanto minorem ventriculus capacitatem habeat in ipsa contractione, vel ipsis contractionibus, quantum sanguinis in arteriam magnam protrudat: (protrudere enim aliquid semper & ante demonstratum est cap. 3. & omnes in Systole fatentur, ex fabrica valuularum persuasi) & verisimili coniectura ponere liceat, in arteriam immitti partem vel quartam vel quintam vel sextam, & minimum octauam.

Ita in homine, protrudi singulis cordis pulsibus supponamus vnciã semis, vel drachmas tres vel drachmam vnam sanguinis, quæ propter impedimontum valuularum in cor remeare non potest.

Cor vna semihora plusquam mille pulsus facit imo in aliquibus, & aliquando bis, ter, vel quater mille. Iam multiplicatis drachmis,

videbis vna ſemihora aut millies drachmas tres, vel drachmas duas, vel vncias quinquies centum , aut talem aliquam proportionatam quantitatem ſanguinis, per cor in arterias transfuſam, maiori ſemper copia quam in vniuerſo corpore contingat reperiri. Similiter in oue, aut cane pertranſit eſto ſcrupulum vnum, in vna cordis contractione, tum vna ſemihora mille ſcrupulos vel circa libras tres & ſemis ſanguinis,in quo corpore plerumque non continetur plus quatuor libris ſanguinis,hoc in oue expertus ſum.

Ita pene, ſupputatione facta ſecundum quod nimium coniectare poſſimus tranſmiſſi ſanguinis,& enumeratis pulſationibus,videatur omnem maſſæ quantitatem ſanguineæ pertranſire de venis in arterias per cor,& ſimiliter per pulmones.

Sed eſto,quod non vna ſemihora,ſed vna hora,vel vna die,vtcumq; manifeſtum facit plus ſanguinis per cor eius pulſu tranſmitti continue,quam vel ingeſtum alimentum poſſit ſuppeditare, vel in venis ſimul contineri.

Nec eſt dicendum,quod cor in ſua contractione aliquando protrudat,aliquando non, vel quaſi nihil, & imaginarium quid. hoc enim ante confirmatum eſt & præterea ſenſui contrarium eſt & rationi. Si enim dilatato corde repleri neceſſe ventriculos ſanguine, contracto neceſſe protrudere ſemper & non parum,cum & ductus non parui & contractio non pauca ſit: in quauis proportione videlicet: Subtripla, ſubſextupla,vel ſuboctupla ſimiliter proportio ſanguinis excluſi,debet eſſe ad ante contentum, & in dilatatione replentem; vti ſe habet capacitas contracti ventriculi ad illam,quæ eſt dilatati. Et cum in dilatatione non contingit repleri nihilo,vel imaginario,Ita in contractione nũquam nihil, vel imaginarium expellit, ſed ſemper aliquid ſecundum proportionem contractionis. Quare concludendum,ſi vno pulſu in homine,vel oue, vel boue, cor emittit drachmam vnam, & mille ſunt pulſus in vna ſemihora,contingit eodem tempore,libras decem & vncias quinque tranſmiſſas eſſe. Si vno pulſu drachmas duas lib.20. & ℥.10. Si ſemivnciam lib.41.& ℥.8. Si vnciam lib.83.℥.4.contingit in vna ſemihora transfuſas (inquam) eſſe de venis in arteriis.

Sed quantum in vnoquoque protrudatur ſingulis pulſationibus,& quando plus,& quando minus,& qua de cauſa,accuratius poſt hæc ex multis obſeruationibus à me forſan palam fiet.

Interim hoc ſcio,& omnes admonitos velim, quod aliquando vberiori

riori copia pertransit sanguis, aliquando minore, & sanguinis circuitus quandoque citius, quandoque tardius peragitur, secundum temperamentum, ætatem, causas externas & internas, & res naturales, & non naturales, somnum, quietem, victum, exercitia, animi pathemata, & similia.

Verum enimuero cum per pulmones & cor, vel minima copia trāseat sanguis, longe vberiori prouentu in arterias, & totum corpus diducitur quam ab alimentorum ingestione suppeditari possibile sit, aut omnino, nisi regressu per circuitum facto.

Hoc etiam palam fit sensu, viuorum dissectionem intuentibus, non solum aperta magna arteria, sed (quod confirmat Galen. in ipso homine) si quæuis vel minima arteria dissecta fuerit, vnius pene semihoræ spatio totam sanguinis massam, & toto corpore, tam venis quam arteriis exhaustam fore.

Similiter Lani oues, omnibus hoc satis attestari possunt quando rescissis arteriis iugularibus, in mactando boue; vnius horæ quad ante minus, totam sanguinis massam exhauriunt, & vasa omnia inanita reddunt in membrorum excissione & tumorum; ex larga sanguinis profusione, itidem comperimus aliquando breui contingere.

Nec perstringit huius argumenti vim, quod per venas effluere in iugulatione, & in membrorum excisione, æque, si non magis quam per arterias dicat quispiam, cum contra se res habet: venæ enim quia subsidunt, quia in ipsis nulla vis cogens foras sanguinem, & quia impedimento valuularum positio est (vt postea patebit) parum admodum reddunt. arteriæ vero impetu impulsum sanguinem foras, largius, impetuosius, tanquam cum Syphone eiectum profundunt: sed experiunda res est, omissa vena & incisa iugulari in oue, vel cane; & quanto impetu, quanta protrusione, quam cito omnem sanguinem è toto corpore, tam venis, quam arteriis contingit inanire admirabile videbitur. Arterias autem nullibi sanguinem è venis recipere, nisi transmissione facta per cor ex ante dictis patet; sed ligando Aortam ad radicem cordis, & aperiendo iugularem, vel aliam arteriam si solum arterias inanitas, & venas repletas conspexeris. non contingit dubitare.

Hinc causam aperte videbis, cur in Anatome, tantum sanguinis reperiatur in venis, parum vero in arteriis, cur multum in dextro ventriculo, parum in sinistro (quæ res antiquis dubitandi occasionem forsan præbuit, & existimandi, spiritus solos in illis concauitatibus contineri

dum vita superstes animal fuerat) causa forsan est quod de venis in arteriis nullibi datur transitus, nisi per cor ipsum, & per pulmones, Cum autem expirauerint, & pulmones moueri desinant, de venæ arteriosæ ramulis, in arteriam venosam, & inde in sinistrum ventriculum cordis sanguis permeare prohibetur (vt in Embryone ante notatum est, prohibitum fuisse ob defectum motus pulmonum, oscilla & porositates cœcas, & inuisibiles aperientium claudentium) cum vero vna cum pulmonibus cor non desinat moueri, sed postea pulsare: & superuiuere pergat: contingit sinistrum ventriculum, & arterias emittere in venas ad habitum corporis sanguinem, & per pulmones non recipere, & proinde quasi inanitas esse.

Sed hoc etiam in rem nostram non parum facit fidei, cum huius nulla alia causa (nisi quam nos ex nostra suppositione afferimus) adduci possit.

Præterea hinc patet, quo magis, aut vehementius arteriæ pulsant, eo citius in omni sanguinis hœmorrhagia inanitum iri corpus.

Hinc etiam in omni Lipothymia, omni timore, & huiusmodi, quādo cor languidius & infirmius, nullo impetu pulsat, omnem contingit hœmorrhagiam sedari & cohiberi.

Hinc etiam est, quod corpore mortuo, postquam cor cessauit pulsare, non poteris, vel è iugularibus, vel cruralibus venis & arteriis apertis vllo conatu massæ sanguineæ, vltra partem mediam elicere. Nec lanio, si boui (postquam eius caput percusserit, & attonitum reddiderit) iugulum prius non secuerit, quam cor pulsare desierit, totum sanguinem exhaurire inde poterit.

Denique hinc de Anastomosi venarum & arteriarum, vbi sit & quomodo sit, & qua de causa, nemo hactenus, super ea, recte quidquam dixisse licet suspicari. ego in illa disquisitione iam sum.

CAPVT X.

Primum suppositum de copia pertranseuntis sanguinis è venis in arterias, & esse sanguinis circuitum ab obiectionibus vindicatur, & experimentis vlterius confirmatur.

HActenus primum suppositum confirmatum est, siue res ad calculum reuocetur, siue ad experimenta, & autopsiam referatur. videlicet:

licet:

licet: quod ſanguis pertranſeat in arterias, maiori copia continue, quam ab alimento ſuppeditari poſſit, ita vt tota maſſa breui ſpatio illac pertranſeunte, neceſſe ſit, vt circuitus fiat, & ſanguis regrediatur.

Verum ſi quis hic dicat, quod magna copia poſſit pertranſire & non neceſſe circuitum fieri, quin ab aſſumptis reſarcire contingat, & exemplo eſſe lactis in mammis prouentus: vacca enim vna die lactis congios tres, vel quatuor vel ſeptem, vel amplius reddit, mulier itidem duas, vel tres heminas alendo infantem, vnum vel duos, ſingulis diebus præbet, quas ab aſſumptis reſtitui manifeſtum eſt. Reſpondendum, quod cor tantundem, vel amplius, vna hora, vel altera, computatione facta, remittere conſtet.

Sin vero nondum perſuaſus, inſtaret, vſque dicendo, quod licet diſſecta arteria, quaſi data & aperta via, præter naturam contingat ſanguinem cum impetu effundi; non tamen ita contingere integro corpore & non dato exitu, & arteriis plenis, vel ſecundum naturam conſtitutis, tantam copiam pertranſire, tam breui ſpatio, adeo, vt regreſſum fieri ſit neceſſe. Reſpondendum, quod ex ante dicta computatione, ſubducta ratione, apparet, quantum cor repletum vlterius continet in ſua dilatatione quam in conſtrictione, tantundem (maiori ex parte) ſingulis pulſationibus emitti, & proinde in tanta copia, pertranſire integro corpore, & ſecundum naturam conſtituto.

Sed in ſerpētibus & piſcibus quibuſdam, ligando venas per aliquod ſpatium infra cor, videbis ſpatium inter ligaturam & cor valde cito inaniri, ita vt regredi ſanguinem (niſi autopſiam neges) aſſerere neceſſe habeas. Poſterius etiā idē clare patebit in ſecundi ſuppoſiti cōfirmatione.

Hæc omnia vno exemplo confirmantes, concludamus, quo fidem oculis propriis adhibere vnuſquiſque poſſit, ſi anguem viuum diſſecuerit, videbit plus quam per integram horam cor placide, diſtincte, pulſare & ſeſe tanquam vermem in conſtrictione (cum oblongum ſit) ſecūdum longitudinem contrahere, propellere; in Syſtole albidiori colore eſſe contra in Diaſtole; & reliqua pene omnia, quibus euidenter hanc veritatem cōfirmatum iri diximus (hic enim omnia longiora & diſtinctiora magis ſunt) ſed hoc peculiariter & luce clarius meridiana experiri licet. Vena caua partem inferiorē cordis ſubingreditur, exit arteria parte ſuperiori, iā cōprehenſa, vena caua vel teuacuſis, vel digito & pollice, ſanguiniſq; curſu intercepto, per aliquod ſpatiū infra cor videbis

expulſu

expulſu, ſtatim pene inaniri illam partem intra digitos & cor, ſanguine exhauſto à cordis pulſu, ſimul cor albidiori multo colore eſſe, etiam in dilatatione ſua, & ob defectum ſanguinis minus eſſe & languidius tandem pulſare, ſic vt emori denique videatur. Contra ſtatim ſoluta vena, color & magnitudo redeunt cordi; poſtea ſi relinquas venam, & arterias ſimiliter per aliquam diſtantiam à corde ligaueris, vel compreſſeris, videbis contra illas turgere, in parte comprehenſa vehementer, & cor vltra modum diſtendi purpureum colorem contrahere vſque ad liuorem & tandem opprimi ſanguine, ſic vt ſuffocatum iri credas: ſoluto vero vinculo rurſus ad naturalem conſtitutionem in colore magnitudine pulſu redire.

Ecce iam, duo ſunt genera mortis, extinctio ob defectum & ſuffocatio ob copiam, hic ad oculos vtriuſque exemplum habere licet; & dictam veritatem autopſia in corde confirmare.

CAPVT XI.

Secundum ſuppoſitum confirmatur.

SEcundum confirmandum à nobis, quo clarius intuentibus appareat, annotanda ſunt experimenta quædam, ex quibus patet ſanguinem in quodcunque membrum per arterias ingredi, & per venas remeare, & arterias vaſa eſſe differentia ſanguinem à corde, & venas vaſa, & vias eſſe regrediendi ſanguinis ad cor ipſum. Et quod in membris, & extremitatibus ſanguis vel per Anaſtomoſin immediate, vel mediate per carnis poroſitates, vel vtroque modo tranſire ab arteriis in venas, ſicut ante in corde & thorace è venis in arterias: vnde in circuitu moueri illinc huc, & hinc, illuc, è centro in extrema ſcilicet, & ab extremis rurſus ad centrum manifeſtum fiat.

Poſtea quin etiam computatione facta ſimiliter, manifeſtum ibidem erit, de copia, quæ neque ab aſſumptis poſſit ſuppeditari, neque ad nutritionem neceſſario requiratur.

Simul etiam de ligaturis manifeſtum erit, & quare ligaturæ attrahant, & quod neque calore, neque dolore, neque vi vacui, neque vlla ante hac cognita cauſa & ſimiliter ligaturæ quam commoditatem & vſum afferre poſſint in medicina, & quomodo hæmorrhagiam ſupprimunt, & prouocant, & qua de cauſa gangrenæ & mortificationes mē-

brorum

brorum inducunt, & sic in castratione animalium quorundam, & tumorum carnosorum & verrucarum exemptione vsui sunt.

Enim vero, quod nemo harum omnium causas & rationes recte assecutus sit, hinc factum est, vt omnes fere, ex antiquorum sententia, in morbis curandis, proponant, & consulant, ligaturas, pauci vero, recta earum administratione, curationibus suis aliquid adiumenti afferant.

Ligatura alia stricta est, alia mediocris.

Strictam ligaturam dico, cum ita arcte vndique constrictum membrum sit fascia, vel laqueo, vt vltra ipsam ligaturam nullibi arterias pulsare percipiatur, tali vtimur in membrorum excisione fluxui sanguinis prospicientes; & tali etiam vtuntur in castratione animalium, & tumorum ablatione, qua ligatura affluxu alimenti, & caloris omnino intercepto, tabescere, & emori testiculos, atque ingentes sarcoses, & postea decidere, videmus.

Mediocrem vero dico ligaturam, quæ vndique membrum comprimit, sed citra dolorem, & sic, vt vltra ligaturam aliquantulum arteriæ pulsare sinat, qualis, attractione, & in sanguinis missione vsui est, nam licet supra cubitum fiat ligatura, tamen arterias in carpo aliquantulum pulsare tactu percipias, si recte in phlebotomia fiat ligatura.

Iam experimentum fiat in brachio hominis, vel adhibita fascia quali in sanguinis missione vtuntur; vel ipsius manus fortiore comprehensione, quod quidem commodius fit in macilento corpore, & cui venæ sint ampliores, & quando (calefacto corpore) calent extrema, & maior quantitas sanguinis in extremitatibus fuerit, & pulsus vehementiores: omnia enim ibi euidentiora apparebunt.

Facta itaque stricta ligatura quam arcte fieri potest vt quis eum ferat constringendo, obseruare licet primum. Quod vltra ligaturam videlicet versus manum, non pulsabit in carpo vel vspiam arteria. Deinde, immediate supra ligaturam incipit arteria, altius suam Diastolem habere, & magis, & altius, & vehementius pulsare, & prope ipsam ligaturam, ęstu q. quodam intumescit, ac si fluxũ interceptum, & transitum inhibitum perrumpere, & reserare conaretur: magisque artéria, quam par sit, ibi repleta apparet Denique manus suum colorem retinebit, & constitutionem, solum tractu temporis refrigerari aliquantulum incipiet, nihil vero attrahitur in eam.

Postquam per aliquod spatium permansit ista ligatura, derepente paululum soluatur in mediocrem, quali vt dixi in sanguinis missione vtuntur: & obseruandum.

Manum totam ſtatim colorari, & diſtendi,& eius venas tumidas,& varicoſas fieri; & ſpatio decem vel duodecim pulſationum illius arteriæ,multo ſanguine impulſo, atq; impacto refertiſſimam manum cernes,& ab illa ligatura mediocri, multam copiam ſanguinis aff tim attractam eſſe,abſque dolore,vel calore vel fuga vacui, vel vlla alia antehac commemorata cauſa.

Si quis diligenter in ipſo illius ſolutionis momento prope ligaturam digitum ad arteriam iam pulſantem applicauerit, quaſi ſubtus præterlabentem ſanguinem ſentiet.

Ipſe porro cuius in brachio fit experimentum,ab ipſa ſolutione ligaturæ ſtrictæ in mediocrem,plane calorem,& ſanguinem, pulſu ingredientem, quaſi ſemoto obſtaculo, illico ſen iet, & aliquid ſecundum ductum arteriarum, tanquam confeſtim inflatum, & ſparſim per manum tranſmiſſum,percipiet, & continuo calefieri manum & diſtendi.

Quemadmodum in ſtricta ligatura, arteriæ ſupra ligaturam diſtendantur, & pulſent, non infra: ita hac mediocri contra, venæ infra ligaturam turgent, & renitentes fiunt, ſupra vero nequaquam & arteriæ minores. Imo,ſi venàs tumidas compreſſeris, (niſi valde fortiter) vix ſupra ligaturam, aut ſanguinem diffundi aut venas diſtendi conſpicies.

Ita ex his cuiuis diligentius obſeruanti,facile eſt noſcere, ſanguinē ingredi per arterias,ipſarum enim ſtricta ligatura nihil attrahitur, manus colorem ſeruat, nihil influit, neque fit diſtenſio:ipſis vero paululum ſolutis (vt in mediocri ligatura) vi & impulſu affatim ſanguinem intus trudi, manum tumidam fieri manifeſtum eſt, vbi ipſæ pulſant, ſcilicet,ſanguis profluit, vt mediocri ligatura in manu: vbi vero non, vt in ſtricta, nequaquam, niſi ſupra, ligaturam. Cum interim venis compreſſis, nihil per ipſas influere poteſt: cuius hoc eſt ſignum,quod infra ligaturam tumidiores multo ſunt, quam ſupra, & quam dempta ligatura ſolent eſſe, & quod compreſſæ, nihil ſuperioribus ſuggerunt ita, quod ligatura impediat regreſſum ſanguinis per venas, ad ſuperiora eaſque infra ligaturam tumidas faciat permanere, clare patet.

Arteriæ vero iuſta de cauſa,non obſtante mediocri ligatura,vi &impulſu cordis ab internis corporis partibus foras vltra ligaturam ſanguinem trudunt, & iſta eſt differentia ſtrictæ ligaturæ à mediocri quod illa (ſtricta ligatura) non ſolum tranſitum ſanguinis in venis, ſed in arteriis

teriis intercipiat hæc(quæ mediocris) vim pulsificam, quo minus vltra ligaturam se exporrigat, ad extimasque corporis partes propellat, sanguinem non impediat.

Adeo vt sic ratiocinari liceat: mediocri ligatura cũ venas turgidas distẽtas esse, & manũ plurimo sanguine impleri vidimus, vnde fit hoc? aut n per venas, aut per arterias, aut per cœcas porositates, infra ligaturam sanguinis aduenit: è venis, non potest: per cœcos ductus, minus: ergo per arterias secundum quod dictum, necesse est: per venas influere non posse, patet; cum non exprimi retro sanguinem contingat supra ligaturam, nisi ablata omni ligatura, quando subito omnes venas detumescere, & sese in superiores partes exonerate, manum dealbari, & sursum omne prius collectum & tumorem & sanguinem affatim euanescere videtur.

Amplius sentiet ipse, cui ita, post multum spatium ligatum corpus aut brachium erat, & manus tumidæ pauloque frigidiores inde redditæ, sentiet (inquam) de solutione mediocris ligaturæ, frigidum quid sursum vsque ad cubitum vel axillas obrepere, vna scilicet cum reuertente sanguine, quem ego frigidi sanguinis recursum (post sanguinis missionem) ad cor vsque (soluto vinculo) in causa fuisse lipothymiæ arbitrarer, quæ etiam robustis aliquando superuenire vidimus, & maxime à solutione ligaturæ, quod vulgo dicunt à conuersione sanguinis.

Præterea, cum statim, à solutione strictæ ligaturæ in mediocrem immissionem sanguinis per arterias, continuo venas intumescere videmus infra ligaturam comprehensas, non autem arterias; Signum est & sanguinem ab arteriis in venas & non contra permeare, & aut anastomosin vasorum esse, aut porositates carnis, & partium solidarum peruias sanguini esse. Item signum est venas plurimas inter se se communicare, quod in ligatura mediocri (supra cubitum facta) multæ attolluntur simul & turgent: ex vna autem venula scalpello, exitu sanguini dato, omnes statim detumescunt & in illam vnam sese exonerantes subsidunt simul pene omnes.

Hinc vnusquisque potest causas attractionis, quæ fit per ligaturas, & forsan omnis fluxionis cognoscere, videlicet (quẽadmodum in manu, per istam ligaturam, quam dico mediocrem) compressæ sunt venæ & sanguis exire non potest. Ita cum per arterias vi (scilicet cordis) impingitur, non potens exire inde vt repleatur, distendatur pars necesse est.

Alias enim qui fieri poteſt? Calor & dolor, & vis vacui attrahunt quidem, ſed vt impleatur tantum pars, non vt diſtendatur aut tumefiat vltra naturalem conſtitutionem, & ob infractum, & arcte impactum vi ſanguinem tam violenter, tam ſubito opprimatur, vt caro continui ſolutionem pati, & vaſa diſrumpi cernantur, nuſquam hoc aut calore, aut dolore, aut vi vacui fieri poſſe, credibile, aut demonſtrabile eſt.

Inſuper & ligatura, contingit, attractionem fieri, abſque omni dolore, colore aut illa vi vacui. Quod ſi à dolore aliquo accideret ſanguinem attrahi, quo modo ad cubitum, ligato brachio, infra ligaturā intumeſcunt, & manus, & digiti & venæ varicoſæ? cum propter ligaturæ compreſſionem eo peruenire ſanguis per venas non poteſt; atque quare ſupra ligaturam, neque tumoris, aut repletionis ſignum, neque venarum turgeſcentiæ, neque omnino attractionis, aut affluxus veſtigium appareat.

Sed attractionis infra ligaturam, & tumefactionis vltra naturæ modum, in manu, & digitis, hæc cauſa manifeſta; nempe, quod ſanguis cū impetu, & affatim ingrediatur, exire vero nequeat. An illa vero omnis tumoris cauſa (vt eſt apud Auicen.) & omnis redundantiæ opprimentis in parte? quia viæ ingreſſus apertæ, egreſſus clauſæ, vnde abundare, & in tumorem attolli neceſſe eſt.

An hinc etiam contingat in tuberculis inflammatoriis, quod quovſque tumor incrementum capeſcit, & non ſit in vltimo ſtatu, ſentitur eo loci pulſus plenus, præſertim calidioribus tumoribus in quibus incrementum derepente fieri ſolet, ſed hæc poſterioris diſquiſitionis ſunt, vti an etiam hinc contingat, quod in me ipſo caſu expertus ſum. Ego è curru delapſus aliquando fronte percuſſus, quo loco arteriæ ramulus à temporibus prorepit, ſtatim ab ipſa percuſſione, ſpatio fere viginti pulſationum tumorem oui magnitudine, abſque vel calore vel multo dolore, paſſus ſum, propter videlicet arteriæ vicinitatem, in locum contuſum: ſanguis affatim, magis & velocius impingebatur.

Hinc vero apparet, qua de cauſa in phlebotomia, quando longius proſilire & maiori impetu exire volumus, ſupra ſectionem ligamus, nō infra; quod ſi per venas inde efflueret tanta copia à partibus ſuperioribus, ligatura illa non modo non adiuuaret ſed impediret, & enim inferius ligandum veriſimilius erat, quo ſanguis inhibitus vberius exeat, ſi ex partibus ſuperioribus eo per venas deſcendens per venas emanaret: ſed cum aliunde per arterias impellitur in venas inferiores, in quibus regreſſus

regreſſus per ligaturam præpeditur, venæ turgent, & diſtentæ ipſum maiori impetu per orificium elidere & longius eiicere poſſunt, ſoluta vero ligatura, viaque regreſſus aperta ecce non amplius, niſi guttatim decidit, & quod omnes norunt, ſi vel vinculum ſolueris in adminiſtranda phlebotomia vel infra ligaueris vel ſtricta nimis ligatura, mẽbrum conſtrinxeris, tum ſanguis abſque impetu exit; Quia ſcilicet via ingreſſus & influxus ſanguinis per arterias intercepta ſit. Stricta illa ligatura arteriarũ, aut regreſſus liberior datur per venas, ligatura ſoluta.

CAPVT XII.

Eſſe ſanguinis circuitum ex ſecundo ſuppoſito confirmato.

HÆc cum ita ſint, conſtat confirmatum iri etiam aliud, quod antea per cor continuo ſanguinem tranſire dicebam: videmus enim ab arteriis ſanguinem in venas dimanare, non è venis in arterias: videmus inſuper vel pene totam maſſam ſanguinis exhauriri poſſe ab ipſo brachio (idque vna vena cuticulari ſcalpello aperta, ſi ſiat ligatura decẽs) videmus præterea, ita impetuoſe & affatim effundi, vt non ſolum breui & cito euacuari qui ante ſectionem in brachio intra ligaturam comprehenſus erat ſanguis, ſed ex toto brachio & toto corpore tam arteriis quam venis.

Quare confiteri neceſſe eſt, primo vi & impetu ſuppeditari, & quod vi impingatur intra ligaturam; vi enim & impulſu exit: & proinde à cordis pulſu & robore, vis enim & impulſio ſanguinis ſolum à corde.

Deinde à corde prouenire hunc fluxum, & per cor tranſitu facto è venis magnis hac effluere, ſimiliter confiteri neceſſe, cum intra ligaturam per arterias ingreditur non per venas, & arteriæ nuſquam ſanguinem è venis recipiunt niſi è ſiniſtro ventriculo cordis.

Neque omnino aliter ex vna vena (facta ſupra ligatura) tantam copiam exhaurire vllo modo potuiſſet, pręſertim tam impetuoſe, affatim, tam facile, tam ſubito, niſi à corde, vi, & impulſu conſecutio fiat hoc dicto modo.

Et ſi hæc ita ſint: hinc præterea de copia computationem facere, & de circulari motu ſanguinis argumentari apertiſſime poſſumus. Si etenim in phlebotomia (eo quo ſolet prorumpere effuſione & impetu) ſi

 quis

quis per ſemihoram prouenire ſineret, nulli dubium, quin maxima (ipſius ſanguinis) parte exhauſta, lypothymia & ſyncope aduentarent, & non ſolum arteriæ, ſed & venæ magnæ pene inanitæ forent. Tranſire ergo rationabile eſt, ſemihoræ illo ſpatio tantundem è vena magna per cor in aortam. Vlterius ſi quot vnciæ per vnum brachium perfluant: vel quot in 20. vel 30. pulſationibus intra mediocrem ligaturam trudantur ſanguinis, ſupputares; daret profecto exiſtimandi copiam, quantum per aliud brachium interea per vtrumque crus, per collum vtrinque, & per alias omnes arterias, & venas corporis interim pertranſeat; quibus omnibus fluxus per pulmones, & cordis ventriculos, nouum continuo ſanguinem ſuggerere debet, idque è venis neceſſarium eſt, circuitum fieri; cum nec ſuppeditari ab aſſumptis poſſit, & longe plus eſt, quam partium nutritioni congruens erat.

Amplius obſeruandum, quod in adminiſtranda phlebotomia, quãdoque contingit hanc veritatem confirmaſſe. Nam recte brachiũ quanquam ligaueris, & ſcalpello debito modo diſſecueris, aptari orificius, & omnibus rite adminiſtratis, tamen ſi timor, aut ex quauis alia cauſa, aut animi pathemate, lipopſychia adueniat, & cor languidius pulſat, nullo modo ſanguis exibit, niſi guttatim: præſertim ſi ligatura ſtrictior paulo facta ſit. ratio eſt, quia compreſſam arteriam languidior pulſus & impellens vis infirmior recludere, & ſanguinem intra ligaturam trudere non valet: imo per pulmones deducere, aut è venis in arterias copioſe transferre, eneruatum & languidum cor non poteſt. Sic eodem modo, & eiſdem de cauſis contingit, & mulierum menſtrua, & omnem hæmorrhagiam ſedari. Ex contrariis etiam hoc patet; quoniam redintegrato animo, amoto metu, cum ad ſe redeunt, iam adaucto robore pulſificante; arterias ſtatim vehementius pulſare etiam in parte ligata, in carpo moueri, & ſanguinem per orificium longius proſilire, continuo ductu videbis.

CAPVT XIII.

Tertium ſuppoſitum confirmatur, & eſſe ſanguinis circuitum ex tertio ſuppoſito.

HActenus de copia pertranſeuntis ſanguinis per cor, & pulmones, in centro corporis, & ſimiliter ab arteriis in venas in habitu corporis. Reſtat, vt, quomodo per venas ab extremitatibus, ad cor, retro ſanguis

guis permeat, & quomodo venæ sint vasa deferentia solum sanguiné, ab extremitatibus ad centrum, explicemus: quo facto, tria illa proposita fundamenta, pro circuitu sanguinis fore aperta, vera, stabilia, ad fidem sufficienter faciendam existimamus.

Hoc autem ex valuulis, quæ in ipsis venarum cauitatibus reperiuntur, & ex illarum vsu, & ocularibus experimentis, satis erit apertum.

Clarissimus Hieronym. Fabr. ab Aq. pendent: peritissimus Anatomicus & venerabilis senex, vel vt voluit Doctiss. Riolanus Iac. Siluius. primus in venis membraneas valuulas delineauit figura sigmoides, vel semilunares portiunculas tunicæ interioris venarum eminentes tenuissimas. Sitæ sunt distantibus in locis vario modo in variis hominibus ad venæ latera connatæ, sursum, versus venarum radices spectantes, & in mediam capacitatem venæ, ambæ (vt plurimum enim duæ sunt) inuicem respicientes, atque se inuicem contingentes, & in extremitatibus ita cohærere, copulari aptæ: vt si quid è radice venarum in ramos vel è maioribus in minores permearet, omnino impediant, & ita sitæ: vt sequentium cornua præcedentium conuexæ medium (& sic alternatis vicibus) respiciant.

Harum valuularum vsum rectum inuentor non est assecutus, nec alii addiderunt: non est enim ne pondere deorsum sanguis in inferiora totus ruat: Sunt namque in iugularibus deorsum spectantes, & sanguinem sursum prohibentes fieri, & non vbique sursum spectantes, sed semper versus radices venarum & vbique versus cordis locum: Ego, vt alii etiam, aliquando in emulgentibus reperi, & in Ramis misenterii versus venam cauam & portam spectantes: adde insuper quod in arteriis nullæ sunt, & notare licet, quod canes, & boues omnes habent valuulas in diuisione cruralium venarum, ad principium ossis sacri, vel in ramis illis prope coxendicem, in quibus nil tale timendum propter erectam staturam.

Nec ob metum Apoplexiæ (vt alii dicunt) sunt in iugularibus valuulæ, quia materia in somno potius per arterias soporales influere in caput apta esset.

Nec vt sanguis in diuaricationibus subsistat, in ramos exiles, & non totus in magis apertos, & capaces irrueret: positæ enim sunt vbi nullæ diuaricationes, licet frequentiores conspici fateor, vbi diuaricationes sunt.

Nec vt motus sanguinis à centro corporis retardetur solum (tarde

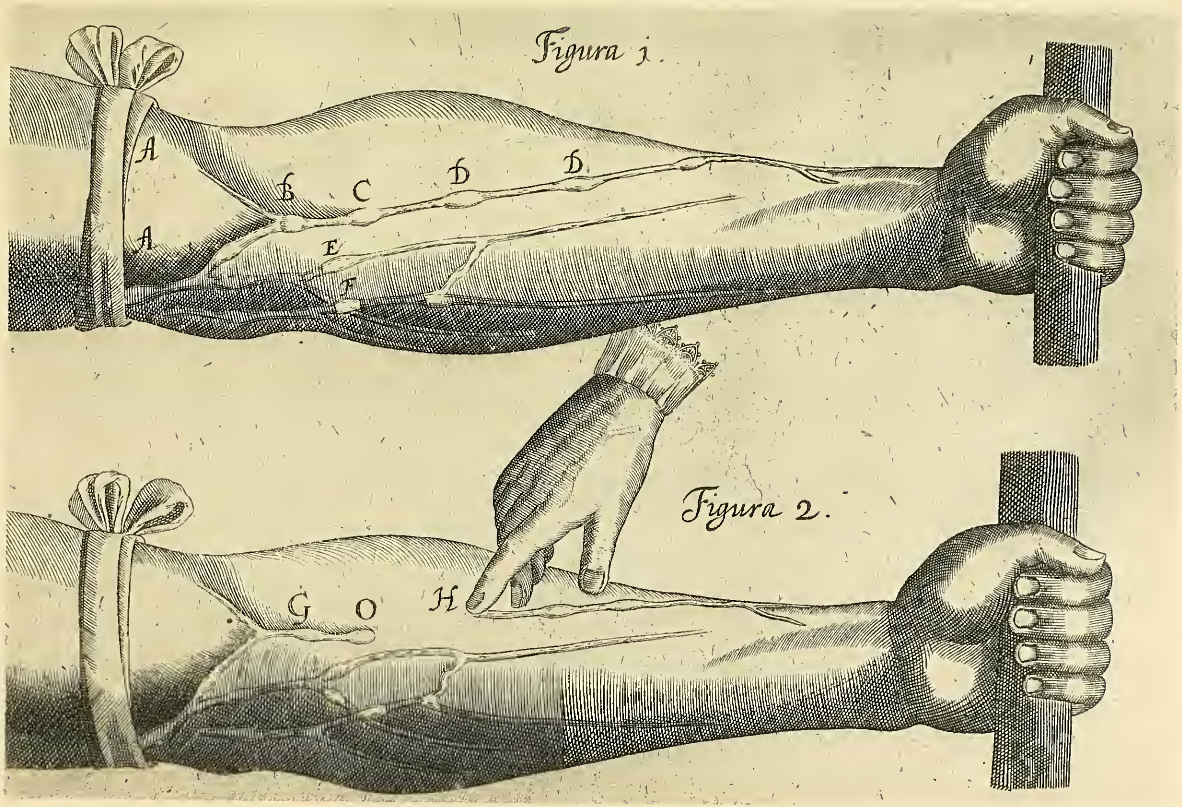
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enim ſatis ſua ſponte,è maioribus in minores ramulas intrudi, è maſſa & fonte ſeparari, aut è locis calidioribus in frigidiora migrare; veriſimilius eſt)Sed omnino valuulæ factæ ſunt,ne à venis magnis in minores moueretur ſanguis & ſic illas dilaceraret, aut variocoſas efficeret, neue à centro corporis in extrema:ſed potius ab extremitatibus ad cētrum progrederetur, ita huic motui valuulæ tenues facile recluduntur, cōtra ium omnino ſupprimunt,& ſic poſitæ & ordinatæ vt ſi quid per cornua ſuperiorum minus prohiberetur tranſitu, ſed quaſi per rimas elaberetur conuexitas ſubſequentium tranſuerſim poſita exciperet,& ſiſteret ne vlterius tranſiret.

Ego illud ſæpiſſime in diſſectione venarum expertus ſum, ſi à radice venarum initio facto, verſus exiles venarum ramos Spicillum mitterem (quanto potuerim artificio) ob impedimentum valuularum longius impellere,non potuiſſe:contra vero forinſecus è ramulis radicem verſus facillime, & pluribus in locis valuulæ binæ ad inuicem ita poſitæ, & aptatæ, vt ad amuſſim (dum eleuantur) in media venæ cauitate cohæreant & vniantur,extremitatibus conuexis inuicem; vt neque viſu, cernere,neque ſatis explorare rimulam aut coitum liceret,contra vero forinſecus intro immiſſo ſtylo cedunt, & (valuularum, quibus curſus fluminum inhibentur in morem)facillime reclinantur, vt motum ſanguinis profectum à corde,& vena caua intercipiant,&ad amuſſim pluribus in locis eleuati inuicem dum clauduntur, omnino inhibeant & ſupprimant,& ſiue ſurſum ad caput,ſiue deorſum ad pedes,ſiue ad latera brachii ſanguinem à corde moueri(ita ſunt conſtitutæ) vt nuſquam ſinant, ſed motui omni ſanguinis qui à maioribus venis auſpicatus, in minores deſinat, aduerſentur & obſiſtant: ei vero qui à venis exilibus incipiens in maiores deſinat, obſecundent liberamque & patentem viam expediant.

Sed quo veritas hæc apertius elucеſcat; ligetur brachium ſupra cubitum viuo homine, tanquam ad mittendum ſanguinem A A per interualla apparebunt, præcipue in ruſticis & varicoſis, tanquam nodi quidam & tubercula B.C.D D.E.F. non ſolum vbi eſt diuaricatio E. F. ſed etiam vbi nulla [C.D.] & iſti nodi à valuulis fiunt. Hoc modo apparentibus in exteriori parte manus vel cubiti ſi à nodo inferius pollice vel digito comprimendo ſanguinem, & de nodo illo ſiue valuula detraxeris] H. 2.figur.]videbis nullum (inhibente omnino valuula) ſubſequi poſſe & venæ portionem (H. O. ſecūdæ fig.) infra tuberculū

& digi-


Figura 1.
A
A
B
C
D
D
E
F
Figura 2.
G
O
H

& digitum detractum, obliteratam, & tamen ſupra tuberculum vel valuulam, ſatis diſtentam [O.G.] immo ſi ita detractum ſanguinem H. & venam inanitam retinueris & altera manu verſus valuularum [O. tertiæ figuræ] partem ſuperiorem diſtentam, deorſum compreſſeris [K. tertiæ,] nulla vi cogi, aut impelli transvaluulam [O.] videbis; ſed quanto maiori conatu, hoc feceris, videbis tanto magis ad valuulam [O. tertiæ] vel tuberculum [O. tertiæ] venam turgentem diſtentam & tamen inferius vacuum eſſe [H.O. tertiæ figuræ.]

Hoc, cum pluribus in locis experiri quis poſſit, apparet valuularum officium in venis idem eſſe cum ſigmoidarum illarum trium, quæ in orificio aortæ & venæ arterioſæ fabrefactæ ſunt, videlicet: vt ad amuſſim claudantur, ne retro ſanguinem tranſeuntem remeare ſinant.

Præterea ligato brachio vti prius A.A. & venis turgentibus, ſi infra tuberculum aliquod ſiue valuulam, venam firmaueris per aliquod ſpatium [L. quartæ] & poſtea ſanguinem ſurſum vſque ſupra valuulam [N.] digito [M.] compuleris, vacuam illam partem venæ permanere videbis [L.N.] nec retro per valuulam regredi poſſe vt eſt [H.O. ſecundæ] ablato vero digito [H.] rurſus repleri ab inferioribus, & eſſe vt [D. C.] vt hinc ſurſum ab inferioribus ad ſuperiora & ad cor ſanguinem moueri in venis & non contrario modo plane conſtet. Et licet aliquibus in locis valuulæ quæ non ita ad amuſſim clauduntur, aut vbi vnica ſolum valuula eſt, tranſitum ſanguinis à centro non videntur prorſus impedire; tamen vt plurimum ita apparet, vel ſaltem quod alicubi negligentius fieri viſum eſt; illud ex ſubſequentium in ordine valuularũ, vel frequentia vel diligentia vel alio modo videtur compenſari, vt venæ viæ patentes & apertæ ſint regredienti ſanguini ad cor, progrediente vero à corde omnino occluſę. Notandum autem hoc inſuper, ligato vt prius brachio & venis turgentibus apparentibus nodis ſiue valuulis viuo homine, infra aliquam valuulam in loco vbi ſubſequentem inueneris; pollicem, qui venam firmet, applicueris; ne quid à manu ſurſum ſanguinis progrediatur & digito deinde ſanguinem ab illa venæ portione, ſurſum ſupra valuulam [L.N.] exprime; vt ante dictum eſt: & ablato digito [L.] ſinito rurſus repleri ab inferioribus [vt D.C.] & rurſus appreſſo pollice, identidem, ſurſum, exprime ſanguinem [L,N. & H.O] & hoc millies in breui tempore facito.

Iam ſi rem ſupputaueris, quantum vna compreſſione, ſurſum, ſupra valuulam ſupponendo, & facta per numerum millenarium multipli-

catione, tantum ſanguinis hoc modo per vnius venæ partem, in non lõgo tempore tranſmiſſum reperies, vt de circuitu ſanguinis, ab eius celeri motu, te perſuaſiſſimum puto ſentires.

Sed ne hoc experimento naturæ vim afferre dicas, in longe diſtantibus valuulis, illud ſi feceris, obſeruando, ablato pollice, quam cito quã celeriter ſanguis ſurſum percurrat, & venam ab inferiori parte repleat, illud ipſum exploratum tibi fore non dubito.

CAPVT XIV.

Concluſio demonſtrationis de ſanguinis circuitu.

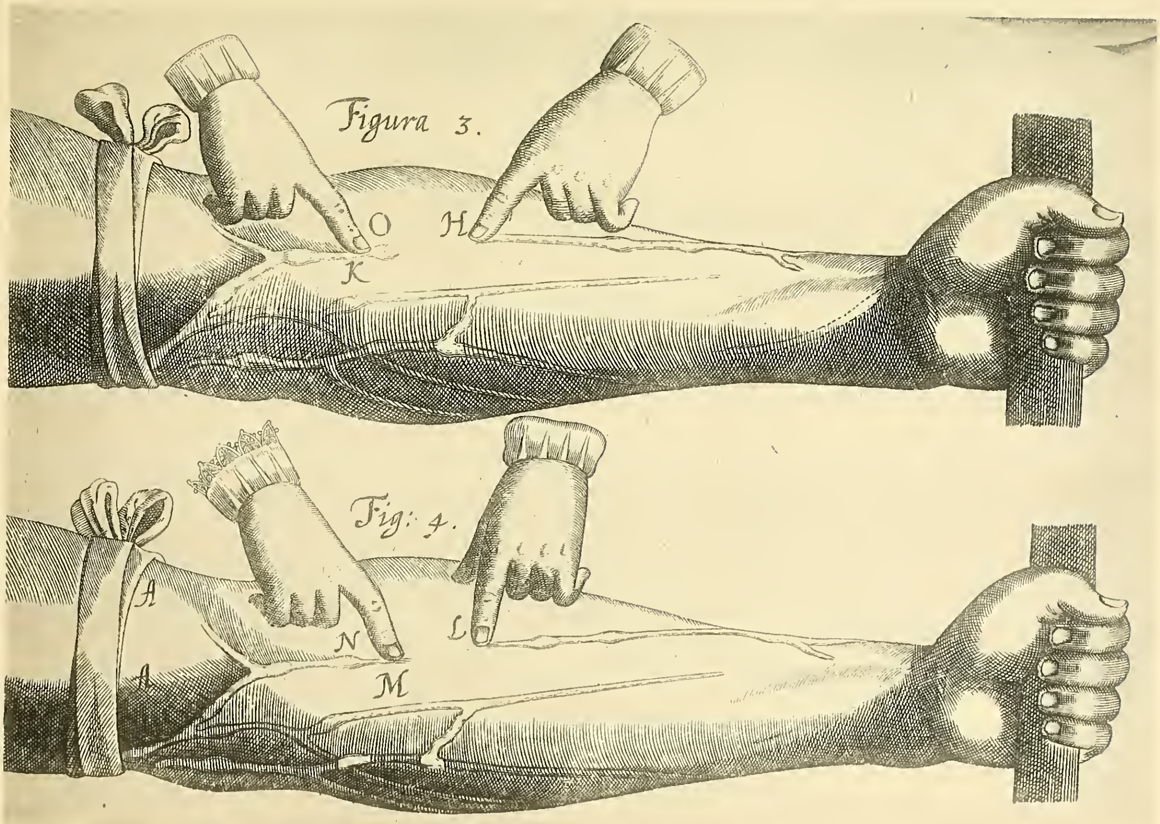
IAm denique noſtram de circuitu ſanguinis ſententiam ferre, & omnibus proponere liceat.

Cum hæc confirmata ſint omnia, & rationibus & ocularibus experimentis, quod ſanguis per pulmones & cor, pulſu ventriculorum pertranſeat, & in vniuerſum corpus impellatur, & immittatur, & ibi in venas & poroſitates carnis obrepat, & per ipſas venas vndique de circũferentia ad centrum ab exiguis venis in maiores remeet, & illinc in venam cauam, ad auriculam cordis tandem veniat, & tanta copia, tanto fluxu, refluxu, hinc per arterias illuc, & illinc per venas huc retro, vt ab aſſumptis ſuppeditari non poſſit, atque multo quidem maiori (quã ſufficiens erat nutritioni) prouentu. Neceſſarium eſt concludere circulari quodam motu in circuitu agitari in animalibus ſanguinem; & eſſe in perpetuo motu, & hanc eſſe actionem ſiue functionem cordis, quam pulſu peragit, & omnino motus & pulſus cordis cauſam vnam eſſe.

CAPVT XV.

Sanguinis circuitus rationibus veriſimilibus confirmatur.

SEd hoc etiam ſubiungere non abs re fuerit, quod ſecundum communes quaſdam ratiocinationes, ita eſſe & conueniens ſit, & neceſſarium. Primum (Ariſtot. de reſpirat. & lib. 2. & 3. de partibus animalium & alibi) cum mors ſit corruptio propter calidi defectum & viuẽtia omnia


Figura 3.
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tia omnia calida, morientia frigida, locum, & originem esse oportet caloris, quasi lares focumque, quo naturæ fomites, & primordia ignis natiui contineantur, & conseruentur, à quo calor & vita in omnes partes tanquam ab origine profluant, & alimentum adueniat, & concoctio, & nutritio, & omnis vegetatio dependeat.

Hunc autem locum cor esse, & hoc principium vitæ, & hoc quo dictum est modo, neminem vellem dubitare.

Sanguini itaq; motu opus est, atque tali, vt ad cor rursus reuertatur, nam in externas corporis partes emandatus longe (vt Arist. 2. de part. animal.) à suo fonte, immotus coagularetur. (motu enim in omnibus calorem & spiritus generari, & conseruari videmus, quiete euanescere) tum à frigore extremorum & ambientis consistens aut gelatus sanguis & spiritibus (vti in mortuis) destitutus: vt rursus à fōte, & origine, tam calorem quam spiritus, & omnino præseruationem suam repetat, & reuertendo redintegraret; necesse fuit.

Videmus vti à frigore exteriori extremitates aliquando algeant vt liuidi & nasus, & manus & genæ quasi mortuorum appareant & sanguis in ipsis (qualis cadauerum, locis pronis solet decumbere) liuorē cōsistat, & membra adeo torpida, & ægre mobilia euadant, vt vitam pene amisisse videantur. Nullo modo profecto rursus (præsertim tam cito) calorem, colorem, & vitam recuperarent, nisi nouo, ab origine affluxu, & appulsu caloris fouerentur: Attrahere enim quomodo possunt, quibus calor & vita pene extincti sunt? aut quibus meatus condensati, & gelato sanguine repleti, quomodo aduenien s admitterent alimentum, & sanguinem; nisi contentum dimitterent? & nisi omnino cor esset, & huiusmodi principium; vbi, his refrigeratis remanerent vita & calor (vt Aristot. respirat. 2.) & vnde nouo, per arterias transmisso, sanguine, calido, spiritibus imbuto. Et quod frigefactum & effætum est propellatur & omnes particulæ calorem languidum & vitalem fomitem, pene extinctum repararent.

Hinc ita est, vt cęteris omnibus partibus & vitam restitui, & sanitatē recuperari, corde illęso cōtingere possit: Corde vero vel refrigerato, vel vitio graui aliquo affecto, totū animal pati, & corruptū iri necesse sit, cū principiū corrūpitur & patitur. Nihil n. est (vt Arist. 3. de partib. animal) quod aut ipsō, aut cæteris quæ ab ipso pēdeant, pbere auxiliū potest. Et hinc obiter forsan ratio est, cur mœrore, amore, inuidia, curis & huiusmodi, tabes & extenuatio contingant aut cacochymia & prouentus

cruditatum, quæ & morbos omnes inducant & homines conficiant: omne namque animi pathema, quod cum dolore, & gaudio, ſpe, aut anxietate humanas exagitat mentes, & ad cor vſque pertingit, & ibi mutationem à naturali conſtitutione intemperie & pulſu & reliquis facit; illud in principio totum alimentum inquinando, & vires infirmando, minime mirum videri debet, quod varia genera morborum incurabilium in membris & corpore ſubinde procreat, quandoquidem totum corpus, in illo caſu vitiato alimento & inopia calidi natiui laborat.

Præter hæc cum alimento viuant omnia animalia interius cõcocto, neceſſe eſt concoctionem perfectam eſſe, & diſtributionem, & proinde locum & conceptaculum adeſſe, vbi perficiatur alimentum & vnde deriuetur in ſingula membra; hic locus autem cor eſt; cum ſolum ex omnibus partibus (non ſolum in vena & arteria coronali priuato vſui) ſed in cauitatibus ſuis tanquam in ciſternis, & promptuario (auriculis ſcilicet & ventriculis) publico vſui, ſanguinem continet: reliquæ omnes partes ſui ipſius tantum cauſa & priuato vſui, in vaſibus duntaxat habent) & cum cor ſolum ita ſitum & conſtitutum, vt inde pulſu ſuo, in omnes partes (idque ſecundum iuſtitiam & proportionem cauitatum arteriarum, vnicuique particulæ inſeruientium) æqualiter diſpenſat, diſtribuit, & indigentib. (quaſi è theſauro & fonte) hoc modo largitur.

Amplius ad hanc diſtributionem & motum ſanguinis, impetu & violentia opus eſt, & impulſore, quale cor eſt: Tunc quia ſanguis ſponte ſua (quaſi verſus principium, vel pars ad totum, vel gutta aquæ ſparſæ ſuper tabulam ad maſſam) facile concentratur & coit: (vti à leuibus cauſis ſolet celerime frigore, timore, horrore & huiuſmodi cauſis aliis.) Tum vltra quia è venis capillaribus in paruas ramificationes & inde in maiores exprimitur motu mebrorum & muſculorum compreſſione, procliuis eſt magis & pronus ſanguis, vt è circumferentia moueatur in centrum, quam è contrario (quamquam valuulæ impedimento nullæ forent) vnde vt principium relinquat, & loca ſtricta & frigidiora iniret, & contra ſpontaneum moueretur. tum violentia opus habet ſanguis tum impulſore, quale cor ſolum eſt, & eo quo dictum eſt modo.

CAPVT XVI.

Sanguinis circuitus ex conſequentibus probatur.

SVnt inſuper problemata, ex hac veritate ſuppoſita, tanquam conſequentia, quæ ad fidem faciendam, veluti à poſteriore non ſunt inutilia,

tilia, & quæ cum aliis multa ambiguitate & obscuritate inuoluta videantur esse: hinc & rationem & causas assignari facile patiantur.

Quemadmodum quæ in contagione videmus, in ictu venenato, & serpentum morsu, aut canis rabidi, in lue venerea, & huiusmodi quomodo illæsa particula contacta tamen totum habitum contingit vitiari (vti lues venerea illæsis aliquando genitalibus primo omnium vel Scapularum, vel capitis dolore, vel aliis Symptomatibus sese prodere solet) & vulnere facto à morsu canis rabidi, curato, febrem tamen, aut reliqua horrenda Symptomata superuenisse experti sumus. Quoniam primum, in particulam impressum contagium, vna cum reuertente sanguine ad cor fertur; & inde totum corpus postea inquinare posse hinc patet: In tertiana febr:, morbifica causa principio cor petens, circa cor & pulmones immoratur, & anhelosos, suspiriosos, ignauos facit, quia principium aggrauatur vitale & sanguis in pulmones impingitur, incrassatur, non transit (hoc ego ex dissectione illorum qui in principio accessionis mortui sunt, expertus loquor) quando semper pulsus frequentes parui, & quandoque inordinati sunt; adaucto vero calore, attenuatione facta materiæ, apertis viis, & transitu facto incalescere vniuersum corpus, pulsus maiores fieri vehementiores, & fit paroxysmus febrilis: dum calor, scilicet, præternaturalis accensus in corde, inde in totum corpus per arterias diffunditur, vna cum materia morbifica; quæ eo modo à natura exuperatur, & dissoluitur.

Cur etiam exterius applicata medicamenta vires intro exercent suas, ac si intro sumpta essent, hinc constet (Colocynthis & Aloe ventrem soluunt, Cantharides vrinas mouent, Allium plantis pedum alligatum expectorat, & cordialia roborat, & huius generis infinita) venas per orificia ab exterius admotis, absorbere aliquid & intro cũ sanguine deferre (non alio modo, quam illæ in mesenterio, ex intestinis Chelum exugunt & ad iecur vna cum sanguine apportant) non irrationabile est forsan dicere.

In mesenterio etenim sanguis, per arterias Celiacas mesentericam superiorem & inferiorem, ingressus; ad intestina progreditur: à quibus vna cum Chylo in venas attracto per illarum venarum frequentissimas ramificationes in portum iecoris reuertitur, & per ipsum in venam cauam sic contingit, vt sanguis in his venis eodem sit imbutus & colore & consistenti, qua in reliquis, contra quam plures opinantur: nec duos contrarios motus in omni Capillari propagine Chyli sursum, sanguinis

deorſum incõuenienter fieri improbabiliter exiſtimare neceſſe eſt. Sed an non ſumma naturæ prouidentia hoc fit; ſi enim Chylus cum ſanguine, crudus cum concocto, æquis portionibus confunderetur, non concoctio tranſmutatio & ſanguific tio exinde proueniret, ſed magis (cũ inuicem actiua & paſſiua ſint) ex alteratorum vnione miſtio, & mediũ quid, vt in perfuſione vini cum aqua & oxicrato; iam vero quando multo cum præterlabente ſanguine exigua portio Chyli hoc modo admiſta ſit, & quaſi nulla notabili proportione, cõtingit illud facilius (quod ait Ariſtoteles) cum vna gutta aquæ addita vini dolio, aut è contra, totum non miſtum, ſed vel vinum vel aqua. Ita in venis meſeraicis diſſectis, non Chymus non Chylus & ſanguis, aut ſeparati, aut confuſi reperiuntur, ſed idem qui in reliquis venis ſanguis & colore, & conſiſtentia ad ſenſum apparet. In quo tamen quia Chyli quiddã inconcoctũ (licet inſenſibiliter) ineſt. Natura iecur appoſuit, in cuius mæandris moras trahat & pleniorem tranſmutationem acquirat, ne præmature crudum ad cor perueniens, vitæ principium obrueret. Hinc in Embryone pene nullus vſus iecoris, vnde vena vmbilicalis iecur manifeſte integra pertranſit & à porta iecoris extat foramen vel anæſtomoſis, vt ſanguis regrediens ab inteſtinis fœtus; non per iecur, ſed in dictam vmbilicalem tranſiens, cor (vna cum materno ſanguine & reuertente à placenta vteri) petat, vnde etiam in prima fœtus conformatione iecur poſterius fieri contingit, & nos etiam in fœtu humano obſeruauimus perfecte delineata omnia membra, imo genitalia diſtincta, nondum tamen iecoris poſita pene rudimenta. Et ſane quouſque membra (vt vel cor ipſum in initio) alba omnia apparent, & præterquam in venis nequidquam ruboris contineant, nihil præter rudem quaſi extra venati ſanguinis collectionem loco iecoris videbis, quam contuſionem quandam vel raptam venam exiſtimares.

Sed in ouo duo quaſi vaſa vmbilicalia, vnum ab albumine integrum pertranſiens iecur & ad cor recte tendens, alterum à luteo in venã portam deſinens: quippe contingit in ouo pullum primum ex albumine tantum formari & nutriri, à luteo vero poſt perfectionem & excluſionẽ (nam & intra inteſtina in ventre pulli contentum poſt multos dies ab excluſione poteſt luteum reperiri, & reſpondet luteum nutrimento lactis cæterorum animalium. ſed hæc conuenientius in obſeruationib. circa fœtus formationem, vbi huius generis poſſunt eſſe problemata plurima, cur hoc prius factum, aut perfectum ſit, illud cur poſterius? & de prin-

de principatu membrorum, quænam particula alterius causa sit? & circa cor plurima, vti cur primum (vt Arist. *de partibus animal.3*) consistens factam sit? & habere videtur in se vitam, motum, & sensum, antequam quidquam reliqui corporis perfectum sit? Et similiter de sanguine quare antea omnia? & qualiter principiũ vitæ & animalis habeat, & moueri atq; huc illuc impelli desiderat? cuius causa cor factũ fuisse videretur.

Eodẽ modo in pulsuum speculatione, cur isti videlicet lethales aut contra & in omnibus generibus ipsorum causas & præsagia contemplando, quid isti significent, quid illud, & quare?

Similiter in Crisibus & expurgationibus naturæ, in nutritione, præsertim distributione alimenti similiter & omni fluxione.

Denique in omni parte medicinæ, Physiologica, Pathologica, Semiotica, Therapeutica, cum quot problemata determinari possunt ex hac data veritate & luce, quanta dubia solui, quot obscura dilucidari, animo mecum reputo: campum inuenio spatiosissimum, vbi longius percurre & latius expatiari adeo possim, vt non solum in volumen excresceret præter institutum meum, hoc opus. Sed mihi forsan vita ad finem faciendum deficeret.

Hoc itaq; loco (*sequente videl. capitulo*) solũmodo, quæ in administranda Anatome circa fabricam cordis & arteriarum comparent, ad suos vsus & causas veras referre enitar, vt sicut quocunque me conuertam, plurima, quæ ex hac veritate lucem recipiant, & hanc vicissim illustriorem reddant, reperiuntur. Ita Anatomicis argumentis firmatam & exornatam p æ cæteris velim.

Est vnum quod licet inter obseruationes nostras de llenis vsu locum habere deberet, tamen hic quoq; obiter annotare non erit impertinẽs. A Ramo splenico in pancreate deducto, è parte superiore venæ oriũtur coronalis, postica, gustrica, & Gastrœpiploica quę omnes plurimis surculis & ramificationibus in ventriculum (veluti meseraicæ in intestina) disseminantur. Similiter à parte inferiori illius splenici deorsum in colon & longanonem vsq; deducitur vena Hæmorrhoidalis, per has venas vtrinq; sanguis regrediens, & succũ crudiorem secũ hinc à ventriculo, aqueum, tenuem nondũ perfecta Chilificatione; illinc crassum & terrestriorem, tanquã è fecibus, reportans in hoc ramo splenico, cõtrariorũ pmistione cõuenienter attẽperatur, & ambos hos succos difficilioris coctionis (pp cõtrarios tamẽ in dispositiones) natura permiscẽdo & multa copia calidioris sãguinis, à liene vberrime (pp multitudinẽ atteriarum)

riarum) ſcaturientis, ſuper infuſa; præparatos magis ad iecoris portus adducit, & defectum vtrorumque extremorum tali venarum fabrica ſupplet & compenſat.

CAPVT XVII.

Confirmatur ſanguinis motus, & circuitus ex apparentibus in Corde, & ex iis, quæ ex diſſectione Anatomica patent.

COr non in omnibus animalibus inuenio diſtinctam eſſe,& ſeparatam particulam,alia enim(quaſi dicas)plant-animalia cor non habent,quia quædam animalia ſunt frigidiora,exiguæ corpulentiæ,mollioris texturę, ſimilaris cuiuſdam conſtitutionis, vt erucarum genus & Lumbricorum, & quæ ex putredine oriuntur, non ſeruantia ſpeciem, plurima, iis cor non eſt vt quibus impulſore non opus ſit, quo alimentũ in extrema deferatur,corpus enim cõnatum & vnum abſque membris indiſtinctum habent, ſic vt contractione, & relatione totius corporis, intro ſumant & expellant, moueant & remoueant alimentum. Plant animalia dicta Oſtrea,Mytili,Spongie & Zoophytorum genera omnia,cor non habent,pro corde enim toto corpore vtuntur; & quaſi totum cor,huiuſmodi animal eſt.

In plurimis & pene omnibus inſectorum generibus, propter corpu lentiæ exiguitatem diſcernere non poſſumus recte; attamen in apibus, muſcis, crabronibus, & huiuſmodi (aliquando ope perſpicilli) licet, pulſans quiddam intueri:etiam in pediculis, quibus tranſitus alimenti per inteſtina (cum translucidum ſit animal) quaſi maculam nigram cernere, inſuper clare poteris multiplicantis illius ſpecilli ope:ſed in exangnibus & frigidiotibus quibuſdam, vt cochleis,conchis,ſquillis,cruſtatis,his omnibus ineſt pulſans particula, (quaſi veſicula quædam vel auricula ſine corde) rarius vero contractionem & pulſum ſuum faciens, & quem non niſi æſtate, aut calidiori tempeſtate diſcernere liceat.

In his ita ſe habet iſta particula; impulſu aliquo opus eſt ad alimenti diſtributionem propter partium organicam varietatem aut denſitatem ſubſtantiæ: ſed rarius fiunt pulſationes, & quandoque non omnino, ob frigiditatem, prout conueniens illis eſt, quæ dubiæ ſunt naturæ, ita vt quando-

quandoque viuere, quandoque emori, videantur, & quandoque vitã animalis agere quandoque plantæ. Quod etiam insectis videtur contingere (cum hyeme latent, & quasi mortua occultantur) vel plantæ vitam tantummodo agant, sed an idem etiam quibusdam sanguinis animalibus accidat, vt ranis, testudinibus, serpentibus, hirundinibus, non iniuria dubitare licet.

In animalibus vero maioribus, calidioribus, vtpote sanguineis impulsore alimẽti, & cum vi forsan maiori, opus est: proinde vti piscibus, serpentibus, lacertulis, testudinibus, ranis & huiusmodi aliis, tum auricula, tum cordis ventriculus vnus, vnde & verissimum illud (Aristot. *de partibus animal. 3.*) quod nullum sangnineum animal careat corde, quo impulsore validiora & robustiora, non solum ab auticula agitetur alimentum, sed longius & celerius protrudatur.

Quin in adhuc maioribus, calidioribus & perfectioribus animalib. vtpote plurimo feruentiori & spirituoso sanguine abundãtibus quo protrudatur, fortius, celerius, & impetu maiori propter corporis magnitudinem, ant habitus densitatem, alimentum, in his robustum cor magis & carnosius desideratur.

Et insuper, quia perfectioribus, perfectiori opus alimento, & vberiori calore natiuo, vt alimentum concoquatur & vlteriorem perfectionem nanciscatur. illis animalibus pulmones habere & alterum vẽtriculum, qui per ipsos pulmones alimentum trudat, conueniebat.

Sic quibuscũque insunt pulmones, vbi duo ventriculi cordis dexter & sinister, & vbicunque dexter ibi sinister quoque inest, non è contra vbi sinister ibi dexter quoque (sinistrum voco ventriculum vsu, non situ, distinctum videlicet, qui sanguinem in totum corpus diffundat nõ in pulmones solum) hinc sinister ventriculus per se cor efficere videtur, & in medio situs, scrobiculis altioribus ita insculptus & maiori diligẽtia fabrefactus est, vt cor sinistri ventriculi gratia factum videatur: & dexter ventriculus quasi famuletur sinistro, nec ad conum eius pertingit, & tenuiori triplo pariete est, & quasi articulationem quandam (vt Arist.) supra sinistrum habeat. Maiori capacitate vero vtpote, qui non solum sinistro materiam, sed & pulmonibus alimentum præbeat.

Notandum vero, quod in Embryone aliter se habent ista, & non tãta differentia fit ventriculorum, sed tanquam in nuce nuclei gemelli, æqualiter pene se habent, & dextri conus ad sinistri summitatem pertingit, vt cor in his (tãquam duplici apice) in cono sit, & hæc quoniam

in his(vt dixi)dum ſanguis non tranſit per pulmones, vtique de dextro cordis ſinu in ſiniſtrum. Ambo per foramen ouale, & tranſitum arterioſum, vt dictum eſt, idem officium traducendi ſanguinem è vena caua in arteriam magnam, pariter præſtant, & in vniuerſum corpus impellunt ęqualiter, vnde æqualis conſtitutio. Cum vero pulmones vſui eſſe, & vniones dictas occludi, ſit tempeſtiuum, tum hęc differentia ventriculorum incipit in robore, & reliquis eſſe; quia dexter duntaxat per pulmones, ſiniſter per totum corpus impellit.

Vltra hæc etiam in corde lacertuli (vt ita dicam) ſiue carnoſæ virgulæ, & fibroſi nexus plurimi (quos Ariſtot. *lib. de reſpirat. & de partibus animaliū 3.* neruos vocat) qui partim ſeparatim diuerſo modo tenduntur; partim in parietibus & mediaſtino (altis factis ſcrobiculis) ſulcatim reconditi tanquam muſculi quidam parui. Qui ad robuſtiorem, & ad validiorem impulſum ſanguinis, & conſtrictionem cordis quaſi ſuccēturiati ſunt, & ſuperadditi cordi, & ad vlteriorem expulſionem ſanguinis auxiliares, & vt (tanquam in nauifunium diligens & artificioſus apparatus) corde vndiquaque ſe contrahente, vndique adiumento forent; & ſanguinem plenius & validius è ventriculis expellerent.

Hoc autem manifeſtum eo, quod quibuſdam animalibus ſint, quibuſdam minime, & omnibus quibus ſunt, illis plures & fortiores, ſiniſtro, quam dextro, & quibuſdam animalibus, in ſiniſtro ſunt, dextro vero nequaquam, & in hominum genere, plures in ſiniſtro quam dextro ventriculo, & plures in ventriculis quam auriculis, & aliquibus in auriculis quaſi nulli. In Toroſis & muſculoſis agreſtibus corporibus, & duriorls habitus, plures; in tenellis corporibus fœminis pauciores.

In quibus animalibus ventriculi cordis intus leues, omnino abſque fibris, lacertulis, neque ſctobiculis fiſſi, (vt auibus minoribus pene omnibus, ſerpentibus, ranis, teſtudinibus, & huiuſmodi, ſic perdica, gallina, piſcibus ſimiliter maxima ex parte) in his neq; nerui (ſiue fibræ dictæ) neque valuulæ tricuſpides in ventriculis repetiuntur. Quibuſdam animalibus dexter ventriculus intus leuis eſt, ſiniſter vero fibroſos illos nexus habet, vt in anſere, Cygno, & auibus grauioribus. In his eadē eſt ratio, quæ in omnibus; cum ſpōgioſi & rari & molles ſint pulmones ad protruſionem ſanguinis per ipſos, vim tantum non deſiderari, proinde dextro ventriculo aut non ſunt illæ fibræ, aut pauciores, infirmiores, non ita carnoſæ, aut muſculos æmulantes. Siniſtri vero ſunt & robuſtiores, & plures, & carnoſiores, & muſculoſi, quia ſiniſter ventriculus

maiori

maiori robore & vi opus habet, quo per vniuersum corpus longius sanguinem prosequi debuerat.

Et hinc etiam medium cordis possidet, & triplo crassiori pariete, & robustiore est sinister ventriculus dextro. Hinc omnia animalia, & inter homines similiter, quo densiori, duriori, & solidiori habitu sunt carnis, & quo magis carnosa, lacertosa habent extrema membra, & magis a corde distantia: eo fibrosum, magis crassum, robustum, & musculosum habent cor. Idque manifestum est, & necessarium. Quo contra rariori textura, & molliori sunt habitu, & corpulentia minore; flaccidum magis, mollius, & intus minus (aut non omnino) fibrosum & eneruatum cor gerunt.

Valuularum similiter sigmoidarum vsum considera; quæ ideo factæ, ne semel missus sanguis in cordis ventriculos regeratur, & in orificio arteriosæ venæ & aortæ (dum sursum eleuatæ, & inuicem coniunctæ triquetram lineam, qualis ab hirundinum morsu relinquitur effingunt) quo arctius obseruatæ, sanguinis refluxum arceant.

Tricuspides in introitu à vena caua, & arteria venosa ianitores, ne cum maxime impellit sanguis, retrolabatur, & ea de causa non insunt omnibus animalibus (vt dixi) neq; quibus insunt, eadem naturæ solertia factæ apparent, sed in aliis exactius, in aliis remissius & negligentius, vt claudantur pro maiori vel minori impulsione à ventriculorum constrictione facta: Ideo in sinistro ventriculo, vti ad maiorem impulsionem diligentior occlusio fiat: duo tantum sunt instar mitræ, vt exactissime claudantur & longe in conum per medium pertingentes (quæ res imposuit forsan Aristoteli vt hunc ventriculum duplicem sectione per transuersum facta existimaret) similiter profecto ne retro in arteriam venosam labatur sanguis, & exinde robur sinistri ventriculi exoluatur, in propellendo per vniuersum corpus, ideo valuulæ istæ mitrales mole, & robore, & exacta clausura, illas in dextro positas exuperant. Hinc etiã necessario nullũ cor sine vẽtriculo cõspicitur cũ lucanar & fons & prõptuariũ esse sanguinis debeat: Idẽ vero in cerebro; nõ semper contingit. Auium n. genera pene omnia nullũ habẽt in cerebro ventriculũ, vt patet in ansere & cygno, quorũ cerebrũ cuniculi cerebro pene magnitudine æquatur. Cuniculi autẽ vẽtriculos, licet in cerebro habeãt, anser tamẽ nõ habet. Similiter vbicunq; cordis vẽtriculus vnus, vna auricula appẽdit, flaccida, cuticularis, intus caua, sanguine referta; vbi duo vẽtriculi, duæ similiter auriculæ. Cõtra vero aliquib. auricula dũtaxat inest

I 2 anima-

animalibus (non autem cordis ventriculus) vel saltem vesica auriculæ analogon, vel vena ipsa in loco dilatata pulsum facit, vt videtur in crabronibus, & apibus, & aliis insectis, quæ non solum pulsum habere, sed & respirationem in illa parte quam caudam nominant, experimentis quibusdã me posse demonstrare arbitror, (vnde ipsam elongare, & contrahere contingit modo frequentius, modo rarius, prout anhelosi magis videntur, & aere magis indigere) sed de his in tractatu de respiratione. Auriculas similiter pulsare aptum est, sese contrahere (vt ante dixi) & sanguinem in ventriculos coniicere, vnde vbicunque est ventriculus auricula necessaria non solum quod vulgo creditur, vt sit sanguinis receptaculum & promptuarium (quid enim opus est pulsatione ad retinendũ) sed motores primi sunt sanguinis auriculæ, præsertim dextra, primum viuens, vltimum moriens (vt ante dictum est) quare necessaria, vt scilicet sanguinem in ventriculum subseruiens infundat Qui vẽtriculus continuo (se ipsum contrahendo) iam ante in motu existentẽ sanguinem commodius elidat, & violentius propellat, vt cum ludas pila à reuerberatione fortius & longius percutiendo quam simplici et proiiciendo, impellere poteris. Quin etiam contra vulgarem opinionem, quia, neque cor, neque aliud quidquam seipsum distendere, sic potest, vt in seipsum attrahere sua diastole quicquam possit, nisi vt spõgia vi prius compressa, dum redit ad constitutionem suam, sed omnem motum localem in animalibus primum fieri, & principium sumpsisse constat à contractione alicuius particulæ: ideo à contractione auricularum coniicitur Sanguis in ventriculos vt ante patefeci, & inde à contractione ventriculorum proiicitur & transfertur.

Quæ veritas de motu locali, & quod immediatum organum motiuum in omni motu, omnium animalium in quo spiritus motiuus (vt Arist. dicit *libro de spiritu & alibi* primo inest) sit contractile, & quemadmodum νεῦρον à νεύω, nuto, contraho dicatur. Et quod Aristot. musculos cognouit, & non operam, omnem motum in animalibus retulit ad neruos siue ad contractile, & proinde illos lacertulos in corde neruos appellauit, si de motiuis organis animalium, & de musculorum fabrica ex obseruationibus nostris, quandoque demonstrare liceret, palam arbitrarer foret.

Quin institutum prosequentes, de auricularum vsu ad ventriculos implendos sanguine, vt ante demonstratum est; contingit; quo magis densum, compactum cor, pariete crassiore, eo auriculæ neruosiores & magis

magis musculosæ ad impellendum & implendum, quibus contra iis tanquam vesica sanguinea, & membrana continens sanguinem apparet (vt in piseibus) (ibi enim tenuissima & adeo ampla est vesica, quæ auriculæ loco est, vt super ipsam cor immntare videatur) vt in quib. piscibus carnosior paulo illa vesica est, perbelle pulmones æmulari & ementiri videtur; vt Cyprino & Barbo tinea & aliis.

In aliquibus hominibus torosis videlicet, & duriores habitus dextrã auriculam ita robustam, & cum lacertulis, & vario fibrarum contextu interius affabre concinnatam reperi; vt aliorum ventriculos robore videretur æquipollere, & mirabar sane in hominibus diuersis, quanta esset differentia.

Sed notandum, quod in fœtu anriculæ longe maiores, quam pro proportione, quia insunt, antequam cor fiat, aut suam functionem præstat (vt ante demonstratum est) & cordis ibi quasi officium faciunt.

Sed quæ in formatione fœtus obseruaui (& antea retuli, & Aristot. in ouo confirmat) maximam huic rei fidem & lucem afferunt. Interea dum fœtus, quasi vermiculus mollis, & (vt dicitur) in iacte est, inest solum punctum sanguineum, siue vesicula pulsans, & quasi vmbilicalis venæ portio, in principio, vel basi dilatata: postea cum fœtus delineatus, iam corpulentiam quandam duriorem habere incipit (ista vesica carnosior & robustior facta in auriculas (mutata constitutione) transit, super quas cordis corpus pullulare incipit, (nondum vllum officium faciens publicum) formato vero fœtu, cum iam distincta ossa à carnibus sunt, & perfectum est animal, & motum habere sentitur, tum cor quoque, intus pulsans habetur, & (vt dixi) vtroque ventriculo sanguinem è vena caua in arteriam transfundit.

Sic natura perfecta & diuina nihil faciens frustra, nec cuipiam animali cor addidit, vbi non erat opus, neque priusquam esset eius vsus fecit; sed iisdem gradibus in formatione cuiuscunque animalis, transiens per omnium animalium constitutiones (vt ita dicam) ouum, vermem, fœtum perfectionem in singulis acquirit. In fœtus formatione, multis obseruationibus hæc alibi confirmanda sunt.

Deniq; non immerito Hippocrates *in lib. de corde* ipsum musculum nuncupauit, cum eadem actio, idem officium sit, videlicet seipsum contrahere, aliud mouere, nempe contentum sanguinem.

Insuper ex fibrarum constitutione motiuaque fabrica vt in musculis ipsis çordis actionem & vsum licet cernere, omnes Anatomici cum

Galeno annotarunt, cordis corpus vario fibrarum ductu videlicet recto, transuerso obliquo fabrefactum esse, at in corde elixo, aliter se habere deprehenditur fibrarum structura. Omnes enim fibræ in parietib. & septo circulares sunt, quales in sphinctere, illę vero quæ sunt in lacertulis, secundum longitudinem obliquæ, porrectæ: sic fit dum omnes fibræ simul contractæ sint, vt contingat, & conũ ad Basin à lacertulis adductum esse, & parietes in orbe circumclusas, & cor vndiq; contractũ esse & ventriculos coarctari, & proinde, cũ ipsius actio sit cõtractio, fũctionem eius esse sanguinem in arterias protrudere existimandum est.

Nec minus Aristoteli de principatu cordis assentiendum, an à cerebro motum & sensum accipiat? an à iecore sanguinem? an sit principium venarum, & sanguinis & huiusmodi? cum qui ipsum redarguere conantur, illud principale argumentum omittunt, aut non intelligunt, quod cor nempe primum subsistens sit, & habeat in se sanguinem, vitam, sensum, motum, antequam aut cerebrum aut iecur facta erant, vel plane distincta apparuerant, vel saltem vllam functionem edere potuerant. Et suis propriis organis ad motum fabricatis, cor, tanquam animal quoddam internum antiquius consistit. Quo primo facto, ab ipso postea fieri, nutriri, conseruari, perfici, totum animal, tanquam huius opus & domicilium, natura voluisset: & cor (tanquam in republ. princeps) penes quem primum & summum imperium vbique gubernans sit. A quo tanquam ab origine in animali, & à fundamento omnis potestas deriuetur, & dependeat.

At amplius circa arterias plurima similiter veritatem hanc illustrant & confirmant, cur arteria venosa non pulsat, cum numeretur inter arterias? aut cur in vena arteriosa pulsus sentitur? quia pulsus arteriarum sanguinis impulsio est.

Cur arteriæ in suæ tunicæ crassitie, & robore tantũ à venis differant, quia sustinent impetum impellentis cordis, & prorumpentis sanguinis.

Hinc cum natura perfecta nihil facit frustra, & in omnibus est sufficiens quanto arteriæ propinquiores cordi sunt, tanto magis à venis in constitutione differunt, & robustiores sunt, & ligamentosæ magis; in vltimis vero disseminationibus ipsarum, vt manu, pede, cerebro, mesenterio, spermaticis ita constitutione similes sunt, vt oculari tunicarum inspectione, alterum ab altero, internoscere difficile sit. Hoc autem iustis de causis sic se habet, nam quo longius arteriæ distant à corde, eo minore multo, vi, ab ictu cordis per multum spacium refracto, percelluntur.

luntur. Adde quod cordis impulsus, cum in omnibus arteriarum truncis, & ramulis sufficiens sanguini esse debuerat, ad diuisiones singulas, quasi partitus imminu tur.

Adeo vt vltimæ diuisiones capillares, arteriosæ videantur venæ non solum constitutione, sed & officio, cum sensibilem pulsum, aut nullem, aut non semper edunt, & nisi cum pulsat cor vehementius, aut arteriola in quauis particula dilatata; aut aperta magis sit. Inde fit vt in dentibus quandoque & tuberculis, quandoque in digitis sentire pulsum, quandoq; non possimus. Vnde pueros, quibus pulsus semper sunt celeres & frequentes, hoc vno signo febricitare certo obseruauerim, & similiter in tenellis & delicatulis; ex compressione digitorum, quando febris in vigore esset, facile pulsu digitorum percipere potuerim.

Ex altera parte, quando cor languidius pulsat, non solum, non in digitis, sed nec in carpo, aut temporibus pulsum sentire contigit, vt in Lypothimia & hystericis symptomatib. & asphyxia, debiliorib. morituris.

Hic ne decipiantur, monendi Chyrurgi, ꝙ in amputatione mēbrorum & tumorum carnòsorum excisione, & vulneribus; sanguis cum vi prosiliens semper exit ab arteria, non autem semper cum saltu, quia exiles arteriæ non pulsant, præsertim si ligatura compressæ fuerint.

Præterea cur vena arteriosa non solum arteriæ constitutionem, & tunicam habeat, sed cur tam multum in crassitie tunicæ non differat à venis, quam aorta, ratio eadem, maiorem à sinistro ventriculo impulsum sustinet aorta, quam illa à dextro & tanto molliori tunicarum constitutione, quam aorta est, quanto dexter ventriculus cordis & pariete, & carne sinistro infi mior, & quanto pulmones in textura, & mollitie, ab habitu corporis & carnis recedunt, tantum differt venæ arteriosæ tunica, ab illa, quæ aortæ. Et semper hæc omnia vbique proportionem seruant, & in hominibus quanto magis torosi, musculosi, & durioris sunt hab.tus, & cor robustum, crassum, densum, & fibrosum magis, tanto & auriculas, & arterias proportionabiliter in omnibus respondentes crassitie, robore habent.

Hinc quibus animalibus leues ventriculi cordis intus sunt, absque villis, aut valuulis, pariete tenuiore, vt piscibus, auibus, serpentibus, & quam plurimis generibus animalium, in illis arteriæ parum aut nihil à venis differunt in tunicarum crassitie.

Amplius cur pulmones tam ampla habent vasa, venam & arteriam, (vt truncus arteriæ venosæ excedat vtroque ramos, crurales, &

iugulares & cur tanti referti sunt sanguine, vt per experientiam & autopsiam scimus (monitu Aristot. non decepti inspectione eorum quos dissectis detraximus animalibus, quorũ sanguis totus effluxerit) causa est, quia inpulmonibus & corde promptuarium fons & thesautus sanguinis, & officina perfectionis est.

Cur similiter arteriam venosam, & sinistrum ventriculum abundare videmus (in Anatomica dissectione) tanta copia sanguinis, & eiusdem quidem, quo dexter ventriculus, & vena arteriosa replentur, similiter nigricantis & grumescentis. Quoniam illinc huc continenter peragrat pulmones sanguis.

Cur denique vena arteriosa dicta, vulgo constitutionem arteriæ; arteria venosa venæ habeant. Quia reuera, & officio & constitutione & omnibus illa arteria, hæc vena sit, contra quam vulgo creditur. Et cur vena arteriosa tam amplum habet orificium quia plus multi defert quam alendis pulmonibus sit necessarium.

Hæc omnia phænomena inter dissecandum obseruanda, & plurima alia, si recte perpensa fuerint, ante dictam veritatem, videntur luculenter illustrare & plane confirmare, simulque vulgaribus opinionibus aduersari: cum quam ob causam ita constituta sint, & facta hæc omnia difficile cuiquam admodum sit, (nisi quo nos modo) explicare.

(?¿?)

FINIS.

Tot erratis, opusculo tam exiguo, lector beneuole, exteinis locis impressio, absente authore & per tantum terræ marisque spatium dissito, his transmissioni epistolarum iniquis temporibus, rei nouitas & nostris correctoribus inusitata, missi exemplaris litera peregrina, veniam exposcunt. Reliqua minutiora facile inter legendum, hæc quæ & tuum intellectum impediant & authoris sensum peruertant, prius necesse est quam legas, (quod facillime poteris) penna corrigas.

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K. Tunc

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AN

ANATOMICAL DISSERTATION

UPON THE

Movement of the Heart and Blood in Animals.

Rendered into English.

To the Most Serene and Invincible CHARLES,

Of Great *Britain*, *France*, *and Ireland*, KING: DEFENDER of the FAITH.

MOST SERENE KING,

The heart of animals is the basis of their life, the principle of the whole, the Sun of their Microcosm, that upon which all movement depends, from which all strength proceeds. The King in like manner is the basis of his Kingdom, the Sun of his World, the heart of the Commonwealth, whence all power derives, all grace appears. What I have here written of the movements of the heart I am the more emboldened to present to your Majesty, according to the Custom of the present age, because nearly all things human are done after human examples and many things in a King are after the pattern of the heart. The Knowledge of his heart therefore will not be useless to a King as embracing a kind of Divine example of his functions,—and it has ever been usual

with men to compare small things with great. Here at all events, best of Kings, placed as you are at the summit of human affairs, you may at once contemplate the prime mover in the body of man and the emblem of your own sovereign power. Accept therefore I most humbly beseech you most serene King with your wonted kindness and forbearance this my new Treatise upon the Heart : you who are yourself the new light of this age and indeed its true heart : a Prince abounding with virtue and grace : to whom we gladly refer all the blessings which *England* enjoys, all the pleasure in our lives.

Your Most August Majesty's

Most Devoted Servant,

William Harvey.

To his very dear Friend

DOCTOR ARGENT,

The Excellent and Accomplished President of the Royal College of Physicians, and to other Learned Physicians, his most esteemed Colleagues.

I HAVE already and repeatedly presented you, my learned friends, with my new views of the movement and function of the heart, in my anatomical lectures; but having now for nine years and more confirmed these views by multiplied demonstrations in your presence, illustrated them by arguments, and freed them from the objections of the most learned and skilful Anatomists, I at length yield to the requests, I might say entreaties, of many, and here present them for general consideration in this Treatise.

Were not the work indeed presented through you, my learned friends, I should scarcely hope that it could come out scatheless and complete; for you have been in general the faithful witnesses of almost all the instances from which I have either collected the truth or confuted error. You have seen my dissections, and at my demonstrations of all that I maintain to be objects of sense, you have been accustomed to stand by and confirm me with your testimony. And

as this book alone declares the blood to course and revolve by a new route, very different from the ancient and beaten pathway trodden for so many ages, and illustrated by such a host of learned and distinguished men, I was greatly afraid lest I might be charged with presumption did I lay my work before the public at home, or send it beyond seas for impression, unless I had first proposed its subject to you, had confirmed its conclusions by ocular demonstrations in your presence, had replied to your doubts and objections, and secured the assent and support of our distinguished President. For I was most intimately persuaded, that if I could make good my proposition before you and our College, illustrious by its numerous body of learned individuals, I had less to fear from others. I even ventured to hope that I should have the comfort of finding all that you had granted me in your entire love of truth, conceded by others who were philosophers like yourselves. True philosophers, who are only eager for truth and knowledge, never regard themselves as already so thoroughly informed, but that they welcome further information from whomsoever and from wheresoever it may come ; nor are they so narrow-minded as to imagine any of the arts or sciences transmitted to us by the ancients, in such a state of forwardness or completeness, that nothing is left for the ingenuity and industry of others. On the contrary, very many maintain that all we know is still infinitely less than all that still remains unknown ; nor do philosophers pin their faith to others' precepts in such wise that they lose their liberty, and cease to give credence to the conclusions of their proper senses. Neither do they swear such fealty to their mistress Antiquity, that they openly, and in sight of all, deny and desert their friend Truth. But even as they see that the credulous and vain are disposed at

the first hint to accept and to believe everything that is proposed to them, so do they observe that the dull and unintellectual are indisposed to see what lies before their eyes, and even deny the light of the noonday sun. They teach us in our course of philosophy to sedulously avoid the fables of the poets and the fancies of the vulgar, as the false conclusions of the sceptics. And then the studious, and good, and true, never suffer their minds to be warped by the passions of hatred and envy, which unfit men duly to weigh the arguments that are advanced in behalf of truth, or to appreciate the proposition that is even fairly demonstrated. Neither do they think it unworthy of them to change their opinion if truth and undoubted demonstration require them to do so. They do not esteem it discreditable to desert error, though sanctioned by the highest antiquity, for they know full well that to err, to be deceived, is human ; that many things are discovered by accident, and that many may be learned indifferently from any quarter, by an old man from a youth, by a person of understanding from one of inferior capacity.

My dear colleagues, I had no purpose to swell this Treatise into a large volume by quoting the names and writings of Anatomists, or to make a parade of the strength of my memory, the extent of my reading, and the amount of my pains ; because I profess both to learn and to teach anatomy, not from books but from dissections ; not from the positions of philosophers but from the fabric of nature ; and then because I do not think it right or proper to strive to take from the ancients any honour that is their due, nor yet to dispute with the moderns, and enter into controversy with those who have excelled in anatomy and been my teachers. I would not charge with wilful falsehood anyone who was

sincerely anxious for truth, nor lay it to anyone's door as a crime that he had fallen into error. I avow myself the partisan of Truth ; and I can indeed say that I have used all my endeavours, bestowed all my pains on an attempt to produce something that should be agreeable to the good, profitable to the learned, and useful to letters.

Farewell, most worthy Doctors,

And think kindly of your Anatomist,

William Harvey.

AN

ANATOMICAL DISSERTATION
UPON THE
MOVEMENT OF THE HEART AND BLOOD IN ANIMALS.

Introduction.

AS we are about to discuss the movement, action, and use of the heart and arteries, it is incumbent upon us first to state what has been thought of these things by others in their writings, and what has been held by the vulgar and by tradition, in order that what is true may be confirmed, and what is false set right by dissection, multiplied experience, and accurate observation.

Almost all anatomists, physicans, and philosophers, up to the present time, have supposed, with *Galen*, that the object of the pulse was the same as that of respiration, and only differed in one particular, this being conceived to depend on the animal, the respiration on the vital faculty; the two, in all other respects, whether with reference to purpose or to motion, comporting themselves alike. Whence it is affirmed, as by *Hieronymus Fabricius* of *Aquapendente*, in his book on 'Respiration,' which has lately appeared, that as the pulsation of the heart and arteries does not suffice for the ventilation and refrigeration of the blood, therefore were the lungs fashioned to surround the heart. From this it appears, that whatever has hitherto been said upon the systole and diastole, or on the movement of the heart and arteries, has been said with especial reference to the lungs.

But as the structure and movements of the heart differ from

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those of the lungs, and the movements of the arteries from those of the chest, so it seems likely that other ends and offices will thence arise, and that the pulsations and uses of the heart, likewise of the arteries, will differ in many respects from the heavings and uses of the chest and lungs. For did the arterial pulse and the respiration serve the same ends; did the arteries in their diastole take air into their cavities, as commonly stated, and in their systole emit fuliginous vapours by the same pores of the flesh and skin; and further, did they, in the time intermediate between the diastole and the systole, contain air, and at all times either air, or spirits, or fuliginous vapours, what should then be said to *Galen*, who wrote a book on purpose to show that by nature the arteries contained blood, and nothing but blood, and consequently neither spirits nor air, as may be readily gathered from the experiments and reasonings contained in the same book? Now if the arteries are filled in the diastole with air then taken into them (a larger quantity of air penetrating when the pulse is large and full), it must come to pass, that if you plunge into a bath of water or of oil when the pulse is strong and full, it ought forthwith to become either smaller or much slower, since the circumambient bath will render it either difficult or impossible for the air to penetrate. In like manner, as all the arteries, those that are deep-seated as well as those that are superficial, are dilated at the same instant, and with the same rapidity, how is it possible that air should penetrate to the deeper parts as freely and quickly through the skin, flesh, and other structures, as through the mere cuticle? And how should the arteries of the fœtus draw air into their cavities through the abdomen of the mother and the body of the womb? And how should seals, whales, dolphins and other cetaceans, and fishes of every description, living in the depths of the sea, take in and emit air by the diastole and systole of their arteries through the infinite mass of waters? For to say that they absorb the air that is present in the water, and emit their fumes into this medium, were to utter something very like a figment. And if the arteries in their systole expel fuliginous vapours from their cavities through the pores of the flesh and skin, why not the spirits,

which are said to be contained in these vessels, at the same time, since spirits are much more subtle than fuliginous vapours or smoke? And if the arteries take in and cast out air in the systole and diastole, like the lungs in the process of respiration, why do they not do the same thing when a wound is made in one of them, as in the operation of arteriotomy? When the windpipe is divided, it is sufficiently obvious that the air enters and returns through the wound by two opposite movements; but when an artery is divided, it is equally manifest that blood escapes in one continuous stream, and that no air either enters or issues. If the pulsations of the arteries fan and refrigerate the several parts of the body as the lungs do the heart, how comes it, as is commonly said, that the arteries carry the vital blood into the different parts, abundantly charged with vital spirits, which cherish the heat of these parts, sustain them when asleep, and recruit them when exhausted? How should it happen that, if you tie the arteries, immediately the parts not only become torpid, and frigid, and look pale, but at length cease even to be nourished? This, according to *Galen*, is because they are deprived of the heat which flowed through all parts from the heart, as its source; whence it would appear that the arteries rather carry warmth to the parts than serve for any fanning or refrigeration. Besides, how can their diastole draw spirits from the heart to warm the body and its parts, and means of cooling them from without? Still further, although some affirm that the lungs, arteries, and heart have all the same offices, they yet maintain that the heart is the workshop of the spirits, and that the arteries contain and transmit them; denying, however, in opposition to the opinion of *Columbus*, that the lungs can either make or contain spirits. They then assert, with *Galen*, against *Erasistratus*, that it is blood, not spirits, which is contained in the arteries.

These opinions are seen to be so incongruous and mutually subversive that every one of them is justly brought under suspicion. That it is blood and blood alone which is contained in the arteries is made manifest by the experiment of *Galen*, by arteriotomy, and by wounds; for from a single divided artery, as

Galen himself affirms in more than one place, the whole of the blood may be withdrawn in the course of half an hour, or less. The experiment of *Galen* alluded to is this: 'If you include a portion of an artery between two ligatures, and slit it open lengthways, you will find nothing but blood;' and thus he proves that the arteries contain blood only. And we too may be permitted to proceed by a like train of reasoning: if we find the same blood in the arteries as in the veins, after having tied them in the same way, as I have myself repeatedly ascertained, both in the dead body and in living animals, we may fairly conclude that the arteries contain the same blood as the veins, and nothing but the same blood. Some, whilst they attempt to lessen the difficulty, affirm that the blood is spirituous and arterious, and virtually concede that the office of the arteries is to carry blood from the heart into the whole of the body, and that they are therefore filled with blood; for spirituous blood is not the less blood on that account. And no one denies that the blood as such, even the portion of it which flows in the veins, is imbued with spirits. But if that portion which is contained in the arteries be richer in spirits, it is still to be believed that these spirits are inseparable from the blood, like those in the veins; that the blood and spirits constitute one body (like whey and butter in milk, or heat in hot water), with which the arteries are charged, and for the distribution of which from the heart they are provided, and that this body is nothing else than blood. But if this blood be said to be drawn from the heart into the arteries by the diastole of these vessels, it is then assumed that the arteries by their distension are filled with blood, and not with the surrounding air, as heretofore; for if they be said also to become filled with air from the ambient atmosphere, how and when, I ask, can they receive blood from the heart? If it be answered: during the systole, I say it seems to be impossible; the arteries would then have to fill while they contracted, to fill, and yet not become distended. But if it be said: during the diastole, they would then, and for two opposite purposes, be receiving both blood and air, and heat and cold, which is improbable. Further, when it is affirmed that the diastole of the heart and arteries is simultaneous, and the

systole of the two is also concurrent, there is another incongruity. For how can two bodies mutually connected, which are simultaneously distended, attract or draw anything from one another; or, being simultaneously contracted, receive anything from each other? And then, it seems impossible that one body can thus attract another body into itself, so as to become distended, seeing that to be distended is to be passive, unless, in the manner of a sponge, which has been previously compressed by an external force, it is returning to its natural state. But it is difficult to conceive that there can be anything of this kind in the arteries. The arteries dilate, because they are filled like bladders or leathern bottles; they are not filled because they expand like bellows. This I think easy of demonstration, and indeed conceive that I have already proved it. Nevertheless, in that book of *Galen* headed 'Quod Sanguis continetur in Arteriis,' he quotes an experiment to prove the contrary: An artery having been exposed, is opened longitudinally, and a reed or other pervious tube is inserted into the vessel through the opening by which the blood is prevented from being lost, and the wound is closed. 'So long,' he says, 'as things are thus arranged, the whole artery will pulsate; but if you now throw a ligature about the vessel and tightly compress its walls over the tube, you will no longer see the artery beating beyond the ligature.' I have never performed this experiment of *Galen's*, nor do I think that it could very well be performed in the living body, on account of the profuse flow of blood that would take place from the vessel which was operated on; neither would the tube effectually close the wound in the vessel without a ligature; and I cannot doubt but that the blood would be found to flow out between the tube and the vessel. Still *Galen* appears by this experiment to prove both that the pulsative property extends from the heart by the walls of the arteries, and that the arteries, whilst they dilate, are filled by that pulsific force, because they expand like bellows, and do not dilate as if they are filled like skins. But the contrary is obvious in arteriotomy and in wounds; for the blood spurting from the arteries escapes with force, now further, now not so far, alternately, or in jets; and the jet always takes place with the

diastole of the artery, never with the systole. By which it clearly appears that the artery is dilated by the impulse of the blood; for of itself it would not throw the blood to such a distance, and whilst it was dilating; it ought rather to draw air into its cavity through the wound, were those things true that are commonly stated concerning the uses of the arteries. Do not let the thickness of the arterial tunics impose upon us, and lead us to conclude that the pulsative property proceeds along them from the heart. For in several animals the arteries do not apparently differ from the veins; and in extreme parts of the body, where the arteries are minutely subdivided, as in the brain, the hand, *&c.*, no one could distinguish the arteries from the veins by the dissimilar characters of their coats; the tunics of both are identical. And then, in an aneurism proceeding from a wounded or eroded artery, the pulsation is precisely the same as in the other arteries, and yet it has no proper arterial covering. To this the learned *Riolanus* testifies along with me, in his Seventh Book.

Nor let anyone imagine that the uses of the pulse and the respiration are the same, because, under the influence of the same causes, such as running, anger, the warm bath, or any other heating thing, as *Galen* says, they become more frequent and forcible together. For, not only is experience in opposition to this idea, though *Galen* endeavours to explain it away, when we see that with excessive repletion the pulse beats more forcibly, whilst the respiration is diminished in amount; but in young persons the pulse is quick, whilst respiration is slow. So it is also in alarm, and amidst care, and under anxiety of mind; sometimes, too, in fevers, the pulse is rapid, but the respiration is slower than usual.

These and other objections of the same kind may be urged against the opinions mentioned. Nor are the views that are entertained of the offices and pulse of the heart, perhaps, less bound up with great and most inextricable difficulties. The heart, it is vulgarly said, is the fountain and workshop of the vital spirits, the centre from whence life is dispensed to the several parts of the body. Yet it is denied that the right ventricle makes spirits, which is rather held to supply nourishment to the lungs.

For these reasons it is maintained that fishes are without any right ventricle (and indeed every animal wants a right ventricle which is unfurnished with lungs), and that the right ventricle is present solely for the sake of the lungs.

1. Why, I ask, when we see that the structure of both ventricles is almost identical, there being the same apparatus of fibres, and braces, and valves, and vessels, and auricles, and each in the same way in our dissections are found to be filled up with blood similarly black in colour, and coagulated—why, I ask, should their uses be imagined to be different, when the action, movement, and pulse of both are the same? If the three tricuspid valves placed at the entrance into the right ventricle prove obstacles to the reflux of the blood into the vena cava, and if the three semilunar valves which are situated at the commencement of the pulmonary artery be there, that they may prevent the return of the blood into the ventricle; why, when we find similar structures in connection with the left ventricle, should we deny that they are there for the same end, of preventing here the egress, there the regurgitation of the blood?

2. And again, when we see that these structures, in point of size, form, and situation, and almost in every respect the same in the left as in the right ventricle, why should it be said that things are arranged in the former for the egress and regress of spirits, in the latter or right ventricle, for the blood? The same arrangement cannot be held fitted to favour or impede the motion of blood and of spirits indifferently.

3. And when we observe that the passages and vessels are severally in relation to one another in point of size, *viz.*, the pulmonary artery to the pulmonary veins, why should the one be destined to a private purpose, that of nourishing the lungs, the other to a public function?

4. And, as *Realdus Columbus* says, it is probable that such a quantity of blood should be required for the nutrition of the lungs; the vessel that leads to them, the vena arteriosa or pulmonary artery being of greater capacity than both the iliac veins?

5. And I further ask, as the lungs are so near, and in continual

movement, and the vessel that supplies them is of such dimensions, what is the use or meaning of the pulse of the right ventricle? and why was Nature reduced to the necessity of adding another ventricle for the sole purpose of nourishing the lungs?

When it is said that the left ventricle draws materials for the formation of spirits, air, and blood, from the lungs and right sinuses of the heart, and in like manner sends spirituous blood into the aorta, drawing fuliginous vapours thence, and sending them by the pulmonary veins into the lungs, whence spirits are at the same time obtained for transmission into the aorta, I ask how, and by what means, is the separation effected? And how comes it that spirits and fuliginous vapours can pass hither and thither without admixture or confusion? If the mitral cuspidate valves do not prevent the egress of fuliginous vapours to the lungs, how should they oppose the escape of air? And how should the semilunars hinder the regress of spirits from the aorta upon each supervening diastole of the heart? Above all, how can they say that the spirituous blood is sent from the pulmonary veins by the left ventricle into the lungs without any obstacle to its passage from the mitral valves, when they have previously asserted that the air entered by the same vessel from the lungs into the left ventricle, and have brought forward these same mitral valves as obstacles to its retrogression? Good God! how should the mitral valves prevent the regurgitation of air and not of blood?

Moreover, when they attribute the pulmonary artery, a vessel of great size, with the coverings of an artery, to none but a kind of private and single purpose, that, namely, of nourishing the lungs, why should the pulmonary vein, which is scarcely so large, which has the coats of a vein, and is soft and lax, be presumed to be made for many—three or four, different uses? For they will have it that air passes through this vessel from the lungs into the left ventricle; that fuliginous vapours escape by it from the heart into the lungs; and that a portion of the spirituous blood is distributed to the lungs for their refreshment.

If they will have it that fumes and air—fumes flowing from, air proceeding towards, the heart—are transmitted by the same

conduit, I reply, that Nature is not wont to construct but one vessel, to contrive but one way for such contrary movements and purposes, nor is anything of the kind seen elsewhere.

If fumes or fuliginous vapours and air permeate this vessel, as they do the pulmonary bronchia, wherefore do we find neither air nor fuliginous vapours when we divide the pulmonary vein? Why do we always find this vessel full of sluggish blood, never of air, whilst in the lungs we find abundance of air remaining?

If anyone will perform *Galen's* experiment of dividing the trachea of a living dog, forcibly distending the lungs with a pair of bellows, and then tying the trachea securely, he will find, when he has laid open the thorax, abundance of air in the lungs, even to their extreme investing tunic, but none in either the pulmonary veins, or left ventricle of the heart. But did the heart either attract air from the lungs, or did the lungs transmit any air to the heart, in the living dog, much more ought this to be the case in the experiment just referred to. Who, indeed, doubts that, did he inflate the lungs of a subject in the dissecting-room, he would instantly see the air making its way by this route, were there actually any such passage for it? But this office of the pulmonary veins, namely, the transference of air from the lungs to the heart, is held of such importance, that *Hieronymus Fabricius* of *Aquapendente*, contends that the lungs were made for the sake of this vessel, and that it constitutes the principal element in their structure.

But I should like to be informed why, if the pulmonary vein were destined for the conveyance of air, it has the structure of a blood-vessel here. Nature had rather need of annular tubes, such as those of the bronchia, in order that they might always remain open, and not be liable to collapse; and that they might continue entirely free from blood, lest the liquid should interfere with the passage of the air, as it so obviously does when the lungs labour from being either greatly oppressed or loaded in a less degree with phlegm, as they are when the breathing is performed with a sibilous or rattling noise.

Still less is that opinion to be tolerated which, as a twofold material, one aëreal, one sanguineous, is required for the compo-

sition of vital spirits, supposes the blood to ooze through the septum of the heart from the right to the left ventricle by certain secret pores, and the air to be attracted from the lungs through the great vessel, the pulmonary vein ; and which consequently, will have it, that there are numerous pores in the septum of the heart adapted for the transmission of the blood. But, by *Hercules*, no such pores can be demonstrated, nor in fact do any such exist. For the septum of the heart is of a denser and more compact structure than any portion of the body, except the bones and sinews. But even supposing that there were foramina or pores in this situation, how could one of the ventricles extract anything from the other—the left, *e.g.*, obtain blood from the right, when we see that both ventricles contract and dilate simultaneously ? Why should we not rather believe that the right took spirits from the left, than that the left obtained blood from the right ventricle, through these foramina ? But it is certainly mysterious and incongruous that blood should be supposed to be most commodiously drawn through a set of obscure or invisible ducts, and air through perfectly open passages, at one and the same moment. And why, I ask, is recourse had to secret and invisible porosities, to uncertain and obscure channels, to explain the passage of the blood into the left ventricle, when there is so open a way through the pulmonary veins ? I own it has always appeared extraordinary to me that they should have chosen to make, or rather to imagine, a way through the thick, hard, dense, and most compact septum of the heart, rather than take that by the open pulmonary vein, or even through the lax, soft, and spongy substance of the lungs at large. Besides, if the blood could permeate the substance of the septum, or could be imbibed from the ventricles, what use were there for the coronary artery and vein, branches of which proceed to the septum itself, to supply it with nourishment ? And what is especially worthy of notice is this : if in the fœtus, where everything is more lax and soft, Nature saw herself reduced to the necessity of bringing the blood from the right into the left side of the heart by the foramen ovale, from the vena cava through the pulmonary vein, how should it be likely that in the adult she should pass it so com-

modiously, and without an effort, through the septum of the ventricles, which has now become denser by age?

Andreas Laurentius,* resting on the authority of *Galen*† and the experience of *Hollerius*, asserts and proves that the serum and pus in empyema, absorbed from the cavities of the chest into the pulmonary vein, may be expelled and got rid of with the urine and fæces through the left ventricle of the heart and arteries. He quotes the case of a certain person affected with melancholia, and who suffered from repeated fainting fits, who was relieved from the paroxysms on passing a quantity of turbid, fetid, and acrid urine. But he died at last, worn out by the disease; and when the body came to be opened after death, no fluid like that he had micturated was discovered either in the bladder or in the kidneys; but in the left ventricle of the heart and cavity of the thorax plenty of it was met with. And then *Laurentius* boasts that he had predicted the cause of the symptoms. For my own part, however, I cannot but wonder, since he had divined and predicted that heterogeneous matter could be discharged by the course he indicates, why he could not or would not perceive, and inform us that, in the natural state of things, the blood might be commodiously transferred from the lungs to the left ventricle of the heart by the very same route.

Since, therefore, from the foregoing considerations and many others to the same effect, it is plain that what has heretofore been said concerning the movement and function of the heart and arteries must appear obscure, inconsistent or even impossible to him who carefully considers the entire subject, it will be proper to look more narrowly into the matter, to contemplate the movement of the heart and arteries, not only in man, but in all animals that have hearts; and also, by frequent appeals to vivisection and continual ocular inspection, to investigate and discern the truth.

* Lib. ix., cap. xi., quest. 12.

† De Locis Affectis, lib. vi., cap. 7.

Chapter I.

The Author's Motives for Writing.

WHEN I first gave my mind to vivisections, as a means of discovering the movements and uses of the heart, and sought to discover these from actual inspection, and not from the writings of others, I found the task so truly arduous, so full of difficulties, that I was almost tempted to think, with *Fracastorius,* that the movement of the heart was only to be comprehended by God. For I could neither rightly perceive at first when the systole and when the diastole took place, nor when and where dilatation and contraction occurred, by reason of the rapidity of the movement, which in many animals is accomplished in the twinkling of an eye, coming and going like a flash of lightning; so that the systole presented itself to me now from this point, now from that; the diastole the same; and then everything was reversed, the movements occurring, as it seemed, variously and confusedly together. My mind was therefore greatly unsettled, nor did I know what I should myself conclude, nor what believe from others. I was not surprised that *Andreas Laurentius* should have written that the movement of the heart was as perplexing as the flux and reflux of *Euripus* had appeared to *Aristotle.*

At length, and by using greater and daily diligence and investigation, making frequent inspection of many and various animals, and collating numerous observations, I thought that I had attained to the truth, that I should extricate myself and escape from this labyrinth, and that I had discovered what I so much desired, both the movement and the use of the heart and arteries. From that time I have not hesitated to expose my views upon these subjects, not only in private to my friends, but also in public, in my anatomical lectures, after the manner of the Academy of old.

These views, as usual, pleased some more, others less; some

chid and calumniated me, and laid it to me as a crime that I had dared to depart from the precepts and opinion of all Anatomists; others desired further explanations of the novelties, which they said were both worthy of consideration, and might perchance be found of signal use. At length, yielding to the requests of my friends, that all might be made participators in my labours, and partly moved by the envy of others, who, receiving my views with uncandid minds and understanding them indifferently, have essayed to traduce me publicly, I have been moved to commit these things to the press, in order that all may be enabled to form an opinion both of me and my labours. This step I take all the more willingly, seeing that *Hieronymus Fabricius* of *Aquapendente*, although he has accurately and learnedly delineated almost every one of the several parts of animals in a special work, has left the heart alone untouched. Finally, if any use or benefit to this department of the republic of letters should accrue from my labours, it will, perhaps, be allowed that I have not lived idly, and, as the old man in the comedy says:

FOR never yet hath anyone attained
To such perfection, but that time, and place,
And use, have brought addition to his knowledge;
Or made correction, or admonished him,
That he was ignorant of much which he
Had thought he knew; or led him to reject
What he had once esteemed of highest price.

So will it, perchance, be found with reference to the heart at this time; or others, at least, starting hence, with the way pointed out to them, advancing under the guidance of a happier genius, may make occasion to proceed more fortunately, and to inquire more accurately.

Chapter II.

Of the Movements of the Heart, as seen in the Dissection of Living Animals.

IN the first place, then, when the chest of a living animal is laid open and the capsule that immediately surrounds the heart is slit up or removed, the organ is seen now to move, now to be at rest ;—there is a time when it moves, and a time when it is at rest.

These things are more obvious in the colder animals, such as toads, frogs, serpents, small fishes, crabs, shrimps, snails and shell-fish. They also become more distinct in warm-blooded animals, such as the dog and hog, if they be attentively noted when the heart begins to flag, to move more slowly, and, as it were, to die : the movements then become slower and rarer, the pauses longer, by which it is made much more easy to perceive and unravel what the movements really are, and how they are performed. In the pause, as in death, the heart is soft, flaccid, exhausted, lying, as it were, at rest.

In the movement, and interval in which this is accomplished, three principal circumstances are to be noted :

1. That the heart is erected, and rises upwards to a point, so that at this time it strikes against the breast, and the pulse is felt externally.

2. That it is everywhere contracted, but more especially towards the sides, so that it looks narrower, relatively longer, more drawn together. The heart of an eel taken out of the body of the animal and placed upon the table or the hand, shows these particulars ; but the same things are manifest in the hearts of small fishes and of those colder animals where the organ is more conical or elongated.

3. The heart being grasped in the hand, is felt to become harder during its action. Now this hardness proceeds from tension, precisely as when the forearm is grasped, its tendons

are perceived to become tense and resilient when the fingers are moved.

4. It may further be observed in fishes, and the colder-blooded animals, such as frogs, serpents, *&c.*, that the heart, when it moves, becomes of a paler colour, when quiescent of a deeper blood-red colour.

From these particulars it appeared to me evident that the movement of the heart consists in a certain universal tension—both contraction in the line of its fibres, and constriction in every sense. It becomes erect, hard, and of diminished size during its action ; the movement is plainly of the same nature as that of the muscles when they contract in the line of their sinews and fibres ; for the muscles, when in action, acquire vigour and tenseness, and from soft become hard, prominent and thickened : in the same manner the heart.

We are therefore authorized to conclude that the heart, at the moment of its action, is at once constricted on all sides, rendered thicker in its parietes and smaller in its ventricles, and so made apt to project or expel its charge of blood. This, indeed, is made sufficiently manifest by the preceding fourth observation in which we have seen that the heart, by squeezing out the blood it contains becomes paler, and then when it sinks into repose and the ventricle is filled anew with blood, that the deeper crimson colour returns. But no one need remain in doubt of the fact, for if the ventricle be pierced the blood will be seen to be forcibly projected outwards upon each movement or pulsation when the heart is tense.

These things, therefore, happen together or at the same instant : the tension of the heart, the pulse of its apex, which is felt externally by its striking against the chest, the thickening of its parietes, and the forcible expulsion of the blood it contains by the constriction of its ventricles.

Hence the very opposite of the opinions commonly received, appears to be true ; inasmuch as it is generally believed that when the heart strikes the breast and the pulse is felt without, the heart is dilated in its ventricles and is filled with blood; but the contrary of this is the fact, and the heart, when it contracts

[and the shock is given], is emptied. Whence the movement which is generally regarded as the diastole of the heart, is in truth its systole. And in like manner the intrinsic movement of the heart is not the diastole but the systole ; neither is it in the diastole that the heart grows firm and tense, but in the systole, for then only, when tense, is it moved and made vigorous.

Neither is it by any means to be allowed that the heart only moves in the line of its straight fibres, although the great *Vesalius,* giving this notion countenance, quotes a bundle of osiers bound in a pyramidal heap in illustration ; meaning, that as the apex is approached to the base, so are the sides made to bulge out in the fashion of arches, the cavities to dilate, the ventricles to acquire the form of a cupping-glass and so to suck in the blood. But the true effect of every one of its fibres is to constringe the heart at the same time that they render it tense ; and this rather with the effect of thickening and amplifying the walls and substance of the organ than enlarging its ventricles. And, again, as the fibres run from the apex to the base, and draw the apex towards the base, they do not tend to make the walls of the heart bulge out in circles, but rather the contrary ; inasmuch as every fibre that is circularly disposed, tends to become straight when it contracts ; and is distended laterally and thickened, as in the case of muscular fibres in general, when they contract, that is, when they are shortened longitudinally, as we see them in the bellies of the muscles of the body at large. To all this let it be added, that not only are the ventricles contracted in virtue of the direction and condensation of their walls, but further, that those fibres, or bands, styled nerves by *Aristotle,* which are so conspicuous in the ventricles of the larger animals, and contain all the straight fibres, (the parietes of the heart containing only circular ones,) when they contract simultaneously, by an admirable adjustment all the internal surfaces are drawn together, as if with cords, and so is the charge of blood expelled with force.

Neither is it true, as vulgarly believed, that the heart by any dilatation or movement of its own, has the power of drawing the blood into the ventricles ; for when it acts and becomes tense,

the blood is expelled ; when it relaxes and sinks together, it receives the blood in the manner and wise which will by-and-by be explained.

Chapter III.

Of the Movements of Arteries, as seen in the Dissection of Living Animals.

IN connection with the movements of the heart these things are further to be observed having reference to the movements and pulses of the arteries:

1. At the moment that the heart contracts, and when the breast is struck, when, in short, the organ is in its state of systole, the arteries are dilated, yield a pulse, and are in the state of diastole. In like manner, when the right ventricle contracts and propels its charge of blood, the pulmonary artery is distended at the same time with the other arteries of the body.

2. When the left ventricle ceases to act, to contract, to pulsate, the pulse in the arteries also ceases ; further, when this ventricle contracts languidly, the pulse in the arteries is scarcely perceptible. In like manner, the pulse in the right ventricle failing, the pulse in the pulmonary artery ceases also.

3. Further, when an artery is divided or punctured, the blood is seen to be forcibly propelled from the wound at the moment the left ventricle contracts ; and, again, when the pulmonary artery is wounded, the blood will be seen spirting forth with violence at the instant when the right ventricle contracts.

So also in fishes, if the vessel which leads from the heart to the gills be divided, at the moment when the heart becomes tense and contracted, at the same moment does the blood flow with force from the divided vessel.

In the same way, when we see the blood in arteriotomy projected now to a greater, now to a less distance, and that the

greater jet corresponds to the diastole of the artery and to the time when the heart contracts and strikes the ribs, and is in its state of systole, we understand that the blood is expelled by the same movement.

From these facts it is manifest, in opposition to commonly received opinions, that the diastole of the arteries corresponds with the time of the heart's systole; and that the arteries are filled and distended by the blood forced into them by the contraction of the ventricles; the arteries, therefore, are distended, because they are filled like sacs or bladders, and are not filled because they expand like bellows. It is in virtue of one and the same cause, therefore, that all the arteries of the body pulsate, *viz.*, the contraction of the left ventricle; in the same way as the pulmonary artery pulsates by the contraction of the right ventricle.

Finally, that the pulses of the arteries are due to the impulses of the blood from the left ventricle, may be illustrated by blowing into a glove, when the whole of the fingers will be found to become distended at one and the same time, and in their tension to bear some resemblance to the pulse. For in the ratio of the tension is the pulse of the heart, fuller, stronger, and more frequent as that acts more vigorously, still preserving the rhythm and volume, and order of the heart's contractions. Nor is it to be expected that because of the movement of the blood, the time at which the contraction of the heart takes place, and that at which the pulse in an artery (especially a distant one) is felt, shall be otherwise than simultaneous: it is here the same as in blowing up a glove or bladder; for in a plenum (as in a drum, a long piece of timber, *&c.*), the stroke and the movement occur at both extremities at the same time. *Aristotle*,* too, has said, 'the blood of all animals palpitates within their veins' (meaning the arteries), 'and by the pulse is sent everywhere simultaneously.' And further,† 'thus do all the veins pulsate together and by successive strokes, because they all depend upon the heart; and, as it is always in movement, so are they likewise always moving

* De Anim., iii., cap. 9.

† De Respir., cap. 20.

together, but by successive movements.' It is well to observe with *Galen*, in this place, that the old philosophers called the arteries veins.

I happened upon one occasion to have a particular case under my care, which plainly satisfied me of this truth : A certain person was affected with a large pulsating tumour on the right side of the neck, called an aneurism, just at that part where the artery descends into the axilla, produced by an erosion of the artery itself, and daily increasing in size ; this tumour was visibly distended as it received the charge of blood brought to it by the artery, with each stroke of the heart : the connection of parts was obvious when the body of the patient came to be opened after his death. The pulse in the corresponding arm was small, in consequence of the greater portion of the blood being diverted into the tumour and so intercepted.

Whence it appears that wherever the movement of the blood through the arteries is impeded, whether it be by compression or infarction, or interception, there do the remote divisions of the arteries beat less forcibly, seeing that the pulse of the arteries is nothing more than the impulse or shock of the blood in these vessels.

Chapter IV.

Of the Movement of the Heart and its Auricles, as seen in the Bodies of Living Animals.

BESIDES the movements already spoken of, we have still to consider those that appertain to the auricles.

Caspar Bauhin and *John Riolan*,* most learned men and skilful Anatomists, inform us, from their observations, that if we carefully watch the movements of the heart in the vivisection of an animal, we shall perceive four movements

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* Bauhin, lib. ii., cap. 21. Riolan, lib. viii., cap. 1.

distinct in time and in place, two of which are proper to the auricles, two to the ventricles. With all deference to such authority, I say that there are four movements distinct in point of place, but not of time; for the two auricles move together, and so also do the two ventricles, in such wise that though the places be four, the times are only two. And this occurs in the following manner:

There are, as it were, two movements going on together; one of the auricles, another of the ventricles; these by no means taking place simultaneously, but the movement of the auricles preceding, that of the heart following; the movement appearing to begin from the auricles and to extend to the ventricles. When all things are becoming languid, and the heart is dying, as also in fishes and the colder blooded animals, there is a short pause between these two movements, so that the heart aroused, as it were, appears to respond to the movement, now more quickly, now more tardily; and at length, when near to death, it ceases to respond by its proper movement, but seems, as it were, to nod the head, and is so slightly moved that it appears rather to give signs of movement to the pulsating auricle, than actually to move. The heart, therefore, ceases to pulsate sooner than the auricles, so that the auricles have been said to outlive it, the left ventricle ceasing to pulsate first of all; then its auricle, next the right ventricle; and, finally, all the other parts being at rest and dead, as *Galen* long since observed, the right auricle still continues to beat; life, therefore, appears to linger longest in the right auricle. Whilst the heart is gradually dying, it is sometimes seen to reply, after two or three contractions of the auricles, roused as it were to action, and making a single pulsation, slowly, unwillingly, and with an effort.

But this especially is to be noted, that after the heart has ceased to beat, the auricles however still contracting, a finger placed upon the ventricles perceives the several pulsations of the auricles, precisely in the same way and for the same reason, as we have said, that the pulses of the ventricles are felt in the arteries, to wit, the distension produced by the jet of blood. And if at this time, the auricles alone pulsating, the point of the heart

be cut off with a pair of scissors, you will perceive the blood flowing out upon each contraction of the auricles. Whence it is manifest that the blood enters the ventricles, not by any attraction or dilatation of the heart, but by being thrown into them by the pulses of the auricles.

And here I would observe, that whenever I speak of pulsations as occurring in the auricles or ventricles, I mean contractions: first the auricles *contract*, and then and subsequently the heart itself *contracts*. When the auricles contract they are seen to become whiter, especially where they contain but little blood; but they are filled as magazines or resevoirs of the blood, which is tending spontaneously and, by its movement in the veins, under pressure towards the centre; the whiteness indicated is most conspicuous towards the extremities or edges of the auricles at the time of their contractions.

In fishes and frogs, and other animals which have hearts with but a single ventricle, and for an auricle have a kind of bladder much distended with blood, at the base of the organ, you may very plainly perceive this bladder contracting first, and the contraction of the heart or ventricle following afterwards.

But I think it right to describe what I have observed of an opposite character: the heart of an eel, of several fishes, and even of some [of the higher] animals taken out of the body, pulsates without auricles; nay, if it be cut in pieces the several parts may still be seen contracting and relaxing; so that in these creatures the body of the heart may be seen pulsating and palpitating, after the cessation of all movement in the auricle. But is not this perchance peculiar to animals more tenacious of life, whose radical moisture is more glutinous, or fat and sluggish, and less readily soluble? The same faculty indeed appears in the flesh of eels, which even when skinned and embowelled, and cut into pieces, are still seen to move.

Experimenting with a pigeon upon one occasion, after the heart had wholly ceased to pulsate, and the auricles too had become motionless, I kept my finger wetted with saliva and warm for a short time upon the heart, and observed, that under the influence of this fomentation it recovered new strength and

life, so that both ventricles and auricles pulsated, contracting and relaxing alternately, recalled as it were from death to life.

Besides this, however, I have occasionally observed, after the heart and even its right auricle had ceased pulsating—when it was *in articulo mortis* in short—that an obscure movement, an undulation or palpitation, remained in the blood itself, which was contained in the right auricle, this being apparent so long as it was imbued with heat and spirit. And indeed a circumstance of the same kind is extremely manifest in the course of the generation of animals, as may be seen in the course of the first seven days of the incubation of the chick: A drop of blood makes its appearance which palpitates, as *Aristotle* had already observed; from this, when the growth is further advanced and the chick is fashioned, the auricles of the heart are formed, which pulsating henceforth give constant signs of life. When at length, and after the lapse of a few days, the outline of the body begins to be distinguished, then is the ventricular part of the heart also produced; but it continues for a time white and apparently bloodless, like the rest of the animal; neither does it pulsate or give signs of movement. I have seen a similar condition of the heart in the human fœtus about the beginning of the third month, the heart being then whitish and bloodless, although its auricles contained a considerable quantity of purple blood. In the same way in the egg, when the chick was formed and had increased in size, the heart too increased and acquired ventricles, which then began to receive and to transmit blood.

And this leads me to remark, that he who inquires very particularly into this matter will not conclude that the heart, as a whole, is the *primum vivens, ultimum moriens*—the first part to live, the last to die—but rather its auricles, or the part which corresponds to the auricles in serpents, fishes, *&c.*, which both lives before the heart and dies after it.

Nay, has not the blood itself or spirit an obscure palpitation inherent in it, which it has even appeared to me to retain after death? and it seems very questionable whether or not we are to say that life begins with the palpitation or beating of the heart. The seminal fluid of all animals—the prolific spirit, as

Aristotle observed, leaves their body with a bound and like a living thing; and nature in death, as *Aristotle** further remarks, retracing her steps, reverts to where she had set out, and returns at the end of her course to the goal whence she had started. As animal generation proceeds from that which is not animal, entity from nonentity, so, by a retrograde course, entity, by corruption, is resolved into nonentity; whence that in animals, which was last created, fails first; and that which was first, fails last.

I have also observed, that almost all animals have truly a heart, not the larger creatures only, and those that have red blood, but the smaller, and pale-blooded ones also, such as slugs, snails, scallops, shrimps, crabs, crayfish, and many others; nay, even in wasps, hornets, and flies, I have, with the aid of a magnifying glass, and at the upper part of what is called the tail, both seen the heart pulsating myself, and shown it to many others.

But in the pale-blooded tribes the heart pulsates sluggishly and deliberately, contracting slowly as in animals that are moribund, a fact that may readily be seen in the snail, whose heart will be found at the bottom of that orifice in the right side of the body which is seen to be opened and shut in the course of respiration, and whence saliva is disharged, the incision being made in the upper aspect of the body, near the part which corresponds with the liver.

This, however, is to be observed: that in winter and the colder season, exsanguine animals, such as the snail, show no pulsations; they seem rather to live after the manner of vegetables, or of those other productions which are therefore designated plant-animals.

It is also to be noted that all animals which have a heart, have also auricles, or something analogous to auricles; and further, that wherever the heart has a double ventricle there are always two auricles present, but not otherwise. If you turn to the production of the chick *in ovo*, however, you will find at

* De Motu Animal., cap. 8.

first no more than a vesicle or auricle, or pulsating drop of blood; it is only by and by, when the development has made some progress, that the heart is fashioned: even so in certain animals not destined to attain to the highest perfection in their organization, such as bees, wasps, snails, shrimps, crayfish, *&c.*, we find only a certain pulsating vesicle, like a sort of red or white palpitating point, as the beginning or principle of their life.

We have a small shrimp in these countries, which is taken in the Thames and in the sea, the whole of whose body is transparent; this creature, placed in a little water, has frequently afforded myself and particular friends an opportunity of observing the movements of the heart with the greatest distinctness, the external parts of the body presenting no obstacle to our view, but the heart being perceived as though it had been seen through a window.

I have also observed the first rudiments of the chick in the course of the fourth or fifth day of the incubation, in the guise of a little cloud, the shell having been removed and the egg immersed in clear tepid water. In the midst of the cloudlet in question there was a bloody point so small that it disappeared during the contraction and escaped the sight, but in the relaxation it reappeared again, red and like the point of a pin; so that betwixt the visible and invisible, betwixt being and not being, as it were, it gave by its pulses a kind of representation of the commencement of life.

Chapter V.

Of the Movement, Action, and Office of the Heart.

FROM these and other observations of a similar nature, I am persuaded it will be found that the movement of the heart is as follows:

First of all, the auricle contracts, and in the course of its contraction forces the blood, (which it contains in ample

quantity as the head of the veins, the store-house and cistern of the blood,) into the ventricle, which being filled, the heart raises itself straightway, makes all its fibres tense, contracts the ventricles, and performs a beat, by which beat it immediately sends the blood supplied to it by the auricle into the arteries. The right ventricle sends its charge into the lungs by the vessel which is called vena arteriosa, but which, in structure and function, and all other respects, is an artery. The left ventricle sends its charge into the aorta, and through this by the arteries to the body at large.

These two movements, one of the ventricles, the other of the auricles, take place consecutively, but in such a manner that there is a kind of harmony or rhythm preserved between them, the two concurring in such wise that but one movement is apparent, especially in the warmer-blooded animals, in which the movements in question are rapid. Nor is this for any other reason than it is in a piece of machinery, in which, though one wheel gives movement to another, yet all the wheels seem to move simultaneously ; or in that mechanical contrivance which is adapted to firearms, where the trigger being touched, down comes the flint, strikes against the steel, produces a spark, which falling among the powder, ignites it, upon which the flame extends, enters the barrel, causes the explosion, propels the ball, and the mark is attained—all of which incidents, by reason of the celerity with which they happen, seem to take place in the twinkling of an eye. So also in deglutition : by the elevation of the root of the tongue, and the compression of the mouth, the food or drink is pushed into the fauces, when the larynx is closed by its muscles and by the epiglottis. The pharynx is then raised and opened by its muscles in the same way as a sac that is to be filled is lifted up, and its mouth dilated. Upon the mouthful being received, it is forced downwards by the transverse muscles, and then carried further by the longitudinal ones. Yet all these movements, though executed by different and distinct organs, are performed harmoniously, and in such order, that they seem to constitute but a single movement and act, which we call deglutition.

Even so does it come to pass with the movements and action of the heart, which constitute a kind of deglutition, a transfusion of the blood from the veins to the arteries. And if anyone, bearing these things in mind, will carefully watch the movements of the heart in the body of a living animal, he will perceive not only all the particulars I have mentioned, *viz.*, the heart becoming erect, and making one continuous movement with its auricles ; but further, a certain obscure undulation and lateral inclination in the direction of the axis of the right ventricle, as if twisting itself slightly in performing its work. And indeed everyone may see, when a horse drinks, that the water is drawn in and transmitted to the stomach at each movement of the throat, which movement produces a sound and yields a pulse both to the ear and the touch ; in the same way it is with each movement of the heart, when there is the delivery of a quantity of blood from the veins to the arteries, a pulse takes place, and can be heard within the chest.

The movement of the heart, then, is entirely of this description, and the one action of the heart is the transmission of the blood and its distribution, by means of the arteries, to the very extremities of the body ; so that the pulse which we feel in the arteries is nothing more than the impulse of the blood derived from the heart.

Whether or not the heart, besides propelling the blood, giving it movement locally, and distributing it to the body, adds anything else to it—heat, spirit, perfection—must be inquired into by and by, and decided upon other grounds. So much may suffice at this time, when it is shown that by the action of the heart the blood is transfused through the ventricles from the veins to the arteries, and distributed by them to all parts of the body.

The above, indeed, is admitted by all, both from the structure of the heart and the arrangement and action of its valves. But still they are like persons purblind or groping about in the dark, for they give utterance to various, contradictory, and incoherent sentiments, delivering many things upon conjecture, as we have already shown.

The grand cause of doubt and error in this subject appears to me to have been the intimate connection between the heart and the lungs. When men saw both the pulmonary artery and the pulmonary veins losing themselves in the lungs, of course it became a puzzle to them to know how or by what means the right ventricle should distribute the blood to the body, or the left draw it from the *venæ cavæ.* This fact is borne witness to by *Galen*, whose words, when writing against *Erasistratus* in regard to the origin and use of the veins and the coction of the blood, are the following :* 'You will reply,' he says, 'that the effect is so ; that the blood is prepared in the liver, and is thence transferred to the heart to receive its proper form and last perfection ; a statement which does not appear devoid of reason; for no great and perfect work is ever accomplished at a single effort, or receives its final polish from one instrument. But if this be actually so, then show us another vessel which draws the absolutely perfect blood from the heart, and distributes it as the arteries do the spirits over the whole body.' Here, then, is a reasonable opinion not allowed, because, forsooth, besides not seeing the true means of transit, he could not discover the vessel which should transmit the blood from the heart to the body at large!

But had anyone been there in behalf of *Erasistratus*, and of that opinion which we now espouse, and which *Galen* himself acknowledges in other respects consonant with reason, to have pointed to the aorta as the vessel which distributes the blood from the heart to the rest of the body, I wonder what would have been the answer of that most ingenious and learned man? Had he said that the artery transmits spirits and not blood, he would indeed sufficiently have answered *Erasistratus*, who imagined that the arteries contained nothing but spirits ; but then he would have contradicted himself, and given a foul denial to that for which he had keenly contended in his writings against this very *Erasistratus*, to wit, that blood in substance is contained in the arteries, and not spirits ; a fact which he

* De Placitis Hippocratis et Platonis, vi.

demonstrated not only by many powerful arguments, but by experiments.

But if the divine *Galen* will here allow, as in other places he does, 'that all the arteries of the body arise from the great artery, and that this takes its origin from the heart; that all these vessels naturally contain and carry blood; that the three semilunar valves situated at the orifice of the aorta prevent the return of the blood into the heart, and that nature never connected them with this, the most noble viscus of the body, unless for some most important end;' if, I say, this Father of Physic concedes all these things—and I quote his own words—I do not see how he can deny that the great artery is the very vessel to carry the blood, when it has attained its highest term of perfection, from the heart for distribution to all parts of the body. Or would he perchance still hesitate, like all who have come after him, even to the present hour, because he did not perceive the route by which the blood was transferred from the veins to the arteries, in consequence, as I have already said, of the intimate connection between the heart and the lungs? And that this difficulty puzzled Anatomists not a little, when in their dissections they found the pulmonary artery and left ventricle full of thick, black, and clotted blood, plainly appears, when they felt themselves compelled to affirm that the blood made its way from the right to the left ventricle by percolating through the septum of the heart. But this fancy I have already refuted. A new pathway for the blood must therefore be prepared and thrown open, and being once exposed, no further difficulty will, I believe, be experienced by anyone in admitting what I have already proposed in regard to the pulse of the heart and arteries, *viz.*, the passage of the blood from the veins to the arteries, and its distribution to the whole of the body by means of these vessels.

Chapter VI.

Of the Course by which the Blood is carried from the Vena Cava into the Arteries, or from the Right into the Left Ventricle of the Heart.

SINCE the intimate connection of the heart with the lungs, which is apparent in the human subject, has been the probable cause of the errors that have been committed on this point, they plainly do amiss who, pretending to speak of the parts of animals generally, as Anatomists for the most part do, confine their researches to the human body alone, and that when it is dead. They obviously do not act otherwise than he who, having studied the forms of a single commonwealth, should set about the composition of a general system of polity; or who, having taken cognizance of the nature of a single field, should imagine that he had mastered the science of agriculture; or who, upon the ground of one particular proposition, should proceed to draw general conclusions.

Had Anatomists only been as conversant with the dissection of the lower animals as they are with that of the human body, the matters that have hitherto kept them in a perplexity of doubt would, in my opinion, have met them freed from every kind of difficulty.

And first, in fishes, in which the heart consists of but a single ventricle, being devoid of lungs, the thing is sufficiently manifest. Here the sac, which is situated at the base of the heart, and is the part analogous to the auricle in man, plainly forces the blood into the heart, and the heart, in its turn, conspicuously transmits it by a pipe or artery, or vessel analogous to an artery; these are facts which are confirmed by simple ocular inspection, as well as by a division of the vessel, when the blood is seen to be projected by each pulsation of the heart.

The same thing is also not difficult of demonstration in those animals that have, as it were, no more than a single ventricle to

the heart, such as toads, frogs, serpents, and lizards, which have lungs in a certain sense, as they have a voice. I have many observations by me on the admirable structure of the lungs of these animals, and matters appertaining, which, however, I cannot introduce in this place. Their anatomy plainly shows us that the blood is transferred in them from the veins to the arteries in the same manner as in higher animals, *viz.*, by the action of the heart; the way, in fact, is patent, open, manifest; there is no difficulty, no room for doubt about it; for in them the matter stands precisely as it would in man, were the septum of his heart perforated or removed, or one ventricle made out of two; and this being the case, I imagine that no one will doubt as to the way by which the blood may pass from the veins into the arteries.

But as there are actually more animals which have no lungs than there are furnished with them, and in like manner a greater number which have only one ventricle than there are with two, it is open to us to conclude, judging from the mass or multitude of living creatures, that for the major part, and generally, there is an open way by which the blood is transmitted from the veins through the sinuses or cavities of the heart into the arteries.

I have, however, cogitating with myself, seen further, that the same thing obtained most obviously in the embryos of those animals that have lungs; for in the fœtus the four vessels belonging to the heart, *viz.*, the vena cava, the pulmonary artery, the pulmonary vein, and the great artery or aorta, are all connected otherwise than in the adult; a fact sufficiently known to every Anatomist. The first contact and union of the vena cava with the pulmonary veins, which occurs before the cava opens properly into the right ventricle of the heart, or gives off the coronary vein, a little above its escape from the liver, is by a lateral anastomosis; this is an ample foramen of an oval form, communicating between the cava and the pulmonary vein, so that the blood is free to flow in the greatest abundance by that foramen from the vena cava into the pulmonary vein, and left auricle, and from thence into the left ventricle. Further, in this foramen

ovale, from that part which regards the pulmonary vein, there is a thin tough membrane, larger than the opening, extended like an operculum or cover; this membrane in the adult blocking up the foramen, and adhering on all sides, finally closes it up, and almost obliterates every trace of it. In the fœtus, however, this membrane is so contrived that falling loosely upon itself, it permits a ready access to the lungs and heart, yielding a passage to the blood which is streaming from the cava, and hindering the tide at the same time from flowing back into that vein. All things, in short, permit us to believe that in the embryo the blood must constantly pass by this foramen from the vena cava into the pulmonary vein, and from thence into the left auricle of the heart; and having once entered there, it can never regurgitate.

Another union is that by the pulmonary artery, and is effected when that vessel divides into two branches after its escape from the right ventricle of the heart. It is as if to the two trunks already mentioned a third were superadded, a kind of arterial canal, carried obliquely from the pulmonary artery, to perforate and terminate in the great artery or aorta. So that in the dissection of the embryo, as it were, two aortas, or two roots of the great artery appear springing from the heart. This canal shrinks gradually after birth, and after a time becomes withered, and finally almost removed, like the umbilical vessels.

The arterial canal contains no membrane or valve to direct or impede the flow of blood in this or in that direction: for at the root of the pulmonary artery, of which the arterial canal is the continuation in the fœtus, there are three semilunar valves, which open from within outwards, and oppose no obstacle to the blood flowing in this direction or from the right ventricle into the pulmonary artery and aorta; but they prevent all regurgitation from the aorta or pulmonic vessels back upon the right ventricle; closing with perfect accuracy, they oppose an effectual obstacle to everything of the kind in the embryo. So that there is also reason to believe that when the heart contracts, the blood is regularly propelled by the canal or passage indicated from the right ventricle into the aorta.

What is commonly said in regard to these two great communications, to wit, that they exist for the nutrition of the lungs, is both improbable and inconsistent; seeing that in the adult they are closed up, abolished, and consolidated, although the lungs, by reason of their heat and movement, must then be presumed to require a larger supply of nourishment. The same may be said in regard to the assertion that the heart in the embryo does not pulsate, that it neither acts nor moves, so that nature was forced to make these communications for the nutrition of the lungs. This is plainly false; for simple inspection of the incubated egg, and of embryos just taken out of the uterus, shows that the heart moves in them precisely as in adults, and that nature feels no such necessity. I have myself repeatedly seen these motions, and *Aristotle* is likewise witness of their reality. 'The pulse,' he observes, 'inheres in the very constitution of the heart, and appears from the beginning, as is learned both from the dissection of living animals and the formation of the chick in the egg.'* But we further observe, that the passages in question are not only pervious up to the period of birth in man, as well as in other animals, as Anatomists in general have described them, but for several months subsequently, in some indeed for several years, not to say for the whole course of life; as, for example, in the goose, snipe, and various birds, and many of the smaller animals. And this circumstance it was, perhaps, that imposed upon *Botallus*, who thought he had discovered a new passage for the blood from the vena cava into the left ventricle of the heart; and I own that when I met with the same arrangement in one of the larger members of the mouse family, in the adult state, I was myself at first led to something of a like conclusion.

From this it will be understood that in the human embryo, and in the embryos of animals in which the communications are not closed, the same thing happens, namely, that the heart by its movement propels the blood by obvious and open passages from the vena cava into the aorta through the cavities of both the

* Lib. de Spiritu, cap. v.

ventricles; the right one receiving the blood from the auricle, and propelling it by the pulmonary artery, and its continuation, named the ductus arteriosus, into the aorta; the left, in like manner, charged by the contraction of its auricle, which has received its supply through the foramen ovale from the vena cava, contracting, and projecting the blood through the root of the aorta into the trunk of that vessel.

In embryos, consequently, whilst the lungs are yet in a state of inaction, performing no function, subject to no movement any more than if they had not been present, Nature uses the two ventricles of the heart as if they formed but one, for the transmission of the blood. The condition of the embryos of those animals which have lungs, whilst these organs are yet in abeyance and not employed, is the same as that of those animals which have no lungs.

So it clearly appears in the case of the fœtus, that the heart by its action transfers the blood from the vena cava into the aorta, and that by a route as obvious and open, as if in the adult the two ventricles were made to communicate by the removal of their septum. We therefore find that in the greater number of animals, in all, indeed, at a certain period of their existence, the channels for the transmission of the blood through the heart are conspicuous. But we have still to inquire why in some creatures—those, namely, that have warm blood, and that have attained to the adult age, man among the number—we should not conclude that the same thing is accomplished through the substance of the lungs, which in the embryo, and at a time when the function of these organs is in abeyance, nature effects by the direct passages described, and which, indeed, she seems compelled to adopt through want of a passage by the lungs; or why it should be better (for Nature always does that which is best) that she should close up the various open routes which she had formerly made use of in the embryo and fœtus, and still uses in all other animals. Not only does she thereby open up no new apparent channels for the passage of the blood, but she even closes those which formerly existed.

And now the discussion is brought to this point, that they

who inquire into the ways by which the blood reaches the left ventricle of the heart and pulmonary veins from the vena cava, will pursue the wisest course if they seek by dissection to discover the causes why in the larger and more perfect animals of mature age, Nature has rather chosen to make the blood percolate the parenchyma of the lungs, than as in other instances chosen a direct and obvious course—for I assume that no other path or mode of transit can be entertained. It must be because the larger and more perfect animals are warmer, and when adult their heat greater—ignited, as I might say, and requiring to be damped or mitigated, that the blood is sent through the lungs, in order that it may be tempered by the air that is inspired, and prevented from boiling up, and so becoming extinguished, or something else of the sort. But to determine these matters, and explain them satisfactorily, were to enter on a speculation in regard to the office of the lungs and the ends for which they exist. Upon such a subject, as well as upon what pertains to respiration, to the necessity and use of the air, *&c.*, as also to the variety and diversity of organs that exist in the bodies of animals in connection with these matters, although I have made a vast number of observations, I shall not speak till I can more conveniently set them forth in a treatise apart, lest I should be held as wandering too wide of my present purpose, which is the use and movement of the heart, and be charged with speaking of things beside the question, and rather complicating and quitting than illustrating it. And now, returning to my immediate subject, I go on with what yet remains for demonstration, *viz.*, that in the more perfect and warmer adult animals, and man, the blood passes from the right ventricle of the heart by the pulmonary artery, into the lungs, and thence by the pulmonary veins into the left auricle, and from there into the left ventricle of the heart. And, first, I shall show that this may be so, and then I shall prove that it is so in fact.

Chapter VII.

The Blood passes through the Substance of the Lungs from the Right Ventricle of the Heart into the Pulmonary Veins and Left Ventricle.

THAT this is possible, and that there is nothing to prevent it from being so, appears when we reflect on the way in which water permeating the earth produces springs and rivulets, or when we speculate on the means by which the sweat passes through the skin, or the urine through the substance of the kidneys. It is well known that persons who use the *Spa* waters, or those of *La Madonna,* in the territories of *Padua,* or others of an acidulous or vitriolated nature, or who simply swallow drinks by the gallon, pass all off again within an hour or two by the bladder. Such a quantity of liquid must take some short time in the concoction : it must pass through the liver ; it is allowed by all that the juices of the food we consume pass twice through this organ in the course of the day ; it must flow through the veins, through the tissue of the kidneys, and through the ureters into the bladder.

To those, therefore, whom I hear denying that the blood, aye, the whole mass of the blood may pass through the substance of the lungs, even as the nutritive juices percolate the liver, asserting such a proposition to be impossible, and by no means to be entertained as credible, I reply, with the poet, that they are of that race of men who, when they will, assent full readily, and when they will not, by no manner of means ; who, when their assent is wanted, fear, and when it is not, fear not to give it.

The substance of the liver is extremely dense, so is that of the kidney ; the lungs, however, are of a much looser texture, and if compared with the kidneys are absolutely spongy. In the liver there is no forcing, no impelling power ; in the lungs the blood is forced on by the pulse of the right ventricle, the necessary effect of whose impulse is the distension of the vessels

and pores of the lungs. And then the lungs, in respiration, are perpetually rising and falling; movements, the effect of which must needs be to open and shut the pores and vessels, precisely as in the case of a sponge, and of parts having a spongy structure, when they are alternately compressed and again are suffered to expand. The liver, on the contrary, remains at rest, and is never seen to be dilated or constricted. Lastly, if no one denies the possibility of the whole of the ingested juices passing through the liver, in man, oxen, and the larger animals generally, in order to reach the vena cava, for this reason, that if nourishment is to continue, these juices must needs get into the veins, and there is no other way but the one indicated, why should not the same arguments be held of avail for the passage of the blood in adults through the lungs? Why not maintain, with *Columbus*, that skilful and learned Anatomist, that it must be so from the capacity and structure of the pulmonary vessels, and from the fact of the pulmonary veins and ventricle corresponding with them, being always found to contain blood, which must needs have come from the veins, and by no other passage save through the lungs? *Columbus*, and we also, from what precedes, from dissections, and other arguments, conceive the thing to be clear. But as there are some who admit nothing unless upon authority, let them learn that the truth I am contending for can be confirmed from *Galen's* own words, namely, that not only may the blood be transmitted from the pulmonary artery into the pulmonary veins, then into the left ventricle of the heart, and from thence into the arteries of the body, but that this is effected by the ceaseless pulsation of the heart and the movement of the lungs in breathing.

There are, as everyone knows, three sigmoid or semilunar valves situated at the orifice of the pulmonary artery, which effectually prevent the blood sent into the vessel from returning into the cavity of the heart. Now *Galen*, explaining the uses of these valves, and the necessity for them, employs the following language:* 'There is everywhere a mutual anastomosis and

* De Usu partium, lib. vi., cap. 10.

inosculation of the arteries with the veins, and they severally transmit both blood and spirit, by certain invisible and undoubtedly very narrow passages. Now if the mouth of the pulmonary artery had stood in like manner continually open, and Nature had found no contrivance for closing it when requisite, and opening it again, it would have been impossible that the blood could ever have passed by the invisible and delicate mouths, during the contractions of the thorax, into the arteries; for all things are not alike readily attracted or repelled; but that which is light is more readily drawn in, the instrument being dilated, and forced out again when it is contracted, than that which is heavy; and in like manner is anything drawn more rapidly along an ample conduit, and again driven forth, than it is through a narrow tube. But when the thorax is contracted, the pulmonary veins, which are in the lungs, being driven inwardly, and powerfully compressed on every side, immediately force out some of the spirit they contain, and at the same time assume a certain portion of blood by those subtle mouths; a thing that could never come to pass were the blood at liberty to flow back into the heart through the great orifice of the pulmonary artery. But its return through this great opening being prevented, when it is compressed on every side, a certain portion of it distils into the pulmonary veins by the minute orifices mentioned.' And shortly afterwards, in the very next chapter, he says: 'The more the thorax contracts, the more it strives to force out the blood, the more exactly do these membranes (*viz.*, the semilunar valves) close up the mouth of the vessel, and suffer nothing to regurgitate.' The same fact he has also alluded to in a preceding part of the tenth chapter: 'Were there no valves, a three-fold inconvenience would result, so that the blood would then perform this lengthened course in vain; it would flow inwards during the diastoles of the lungs, and fill all their arteries; but in the systoles, in the manner of the tide, it would ever and anon, like the *Euripus*, flow backwards and forwards by the same way, with a reciprocating movement, which would nowise suit the blood. This, however, may seem a matter of little moment; but if it meantime appear that the function of respiration suffer, then I

think it would be looked upon as no trifle, *&c.*' Shortly afterwards he says: 'And then a third inconvenience, by no means to be thought lightly of, would follow, were the blood moved backwards during the expirations, had not our Maker instituted those supplementary membranes.' Whence in the eleventh chapter, he concludes: 'That they (the valves) have all a common use, and that it is to prevent regurgitation or backward movement; each, however, having a proper function, the one set drawing matters from the heart, and preventing their return, the other drawing matters into the heart, and preventing their escape from it. For Nature never intended to distress the heart with needless labour, neither to bring aught into the organ which it had been better to have kept away, nor to take from it again aught which it was requisite should be brought. Since, then, there are four orifices in all, two in either ventricle, one of these induces, the other educes.' And again he says: 'Further, since there is one vessel, which consists of a simple covering implanted in the heart, and another, which is double, extending from it, (*Galen* is here speaking of the right side of the heart, but I extend his observations to the left side also,) a kind of reservoir had to be provided, to which both belonging, the blood should be drawn in by one, and emitted by the other.'

This argument *Galen* adduces for the transit of the blood by the right ventricle from the vena cava into the lungs; but we can use it with still greater propriety, merely changing the terms, for the passage of the blood from the veins through the heart into the arteries. From *Galen*, however, that great man, that Father of Physic, it clearly appears that the blood passes through the lungs from the pulmonary artery into the minute branches of the pulmonary veins, urged to this both by the pulses of the heart and by the movements of the lungs and thorax; that the heart, moreover, is incessantly receiving and expelling the blood by and from its ventricles, as from a magazine or cistern, and for this end it is furnished with four sets of valves, two serving for the induction and two for the eduction of the blood, lest, like the *Euripus*, it should be incommodiously sent hither and thither, or flow back into the cavity which it should have quitted, or quit the

part where its presence was required, and so the heart might be oppressed with labour in vain, and the office of the lungs be interfered with.* Finally, our position that the blood is continually permeating from the right to the left ventricle, from the vena cava into the aorta, through the porous structure of the lungs, plainly appears from this, that since the blood is incessantly sent from the right ventricle into the lungs by the pulmonary artery, and in like manner is incessantly drawn from the lungs into the left ventricle, as appears from what precedes and the position of the valves, it cannot do otherwise than pass through continuously. And then, as the blood is incessantly flowing into the right ventricle of the heart, and is continually passed out from the left, as appears in like manner, and as is obvious both to sense and reason, it is impossible that the blood can do otherwise than pass continually from the vena cava into the aorta.

Dissection consequently shows distinctly what takes place in the majority of animals, and indeed in all, up to the period of their maturity; and that the same thing occurs in adults is equally certain, both from *Galen's* words, and what has already been said, only that in the former the transit is effected by open and obvious passages, in the latter by the hidden porosities of the lungs and the minute inosculations of vessels. It therefore appears that, although one ventricle of the heart, the left to wit, would suffice for the distribution of the blood over the body, and its eduction from the vena cava, as indeed is done in those creatures that have no lungs, Nature, nevertheless, when she ordained that the same blood should also percolate the lungs, saw herself obliged to add the right ventricle, the pulse of which should force the blood from the vena cava through the lungs into the cavity of the left ventricle. In this way, it may be said that the right ventricle is made for the sake of the lungs, and for the transmission of the blood through them, not for their nutrition; for it were unreasonable to suppose that the lungs

* See the Commentary of the learned *Hofmann* upon the Sixth Book of *Galen*, 'De Usu partium,' a work which I first saw after I had written what precedes.

should require so much more copious a supply of nutriment, and that of so much purer and more spirituous a nature as coming immediately from the ventricle of the heart, than either the brain with its peculiarly pure substance, or the eyes with their lustrous and truly admirable structure, or the flesh of the heart itself, which is more suitably nourished by the coronary artery.

Chapter VIII.

Of the Quantity of Blood passing through the Heart from the Veins to the Arteries; and of the Circular Movement of the Blood.

THUS far I have spoken of the passage of the blood from the veins into the arteries, and of the manner in which it is transmitted and distributed by the action of the heart; points to which some, moved either by the authority of *Galen* or *Columbus*, or the reasonings of others, will give in their adhesion. But what remains to be said upon the quantity and source of the blood which thus passes, is of a character so novel and unheard-of that I not only fear injury to myself from the envy of a few, but I tremble lest I have mankind at large for my enemies, so much doth wont and custom become a second nature. Doctrine once sown strikes deeply its root, and respect for antiquity influences all men. Still the die is cast, and my trust is in my love of truth, and the candour of cultivated minds. And sooth to say, when I surveyed my mass of evidence, whether derived from vivisections, and my various reflections on them, or from the study of the ventricles of the heart and the vessels that enter into and issue from them, the symmetry and size of these conduits,—for Nature doing nothing in vain, would never have given them so large a relative size without a purpose,—or from observing the arrangement and intimate structure of the valves in particular, and of the other

parts of the heart in general, with many things besides, I frequently and seriously bethought me and long revolved in my mind, what might be the quantity of blood which was transmitted, in how short a time its passage might be effected, and the like. But not finding it possible that this could be supplied by the juices of the ingested aliment without the veins on the one hand becoming drained, and the arteries on the other getting ruptured through the excessive charge of blood, unless the blood should somehow find its way from the arteries into the veins, and so return to the right side of the heart; I began to think whether there might not be A MOVEMENT, AS IT WERE, IN A CIRCLE. Now this I afterwards found to be true; and I finally saw that the blood, forced by the action of the left ventricle into the arteries, was distributed to the body at large, and its several parts, in the same manner as it is sent through the lungs, impelled by the right ventricle into the pulmonary artery, and that it then passed through the veins and along the vena cava, and so round to the left ventricle in the manner already indicated. This movement we may be allowed to call circular, in the same way as *Aristotle* says that the air and the rain emulate the circular movement of the superior bodies; for the moist earth, warmed by the sun, evaporates; the vapours drawn upwards are condensed, and descending in the form of rain, moisten the earth again. By this arrangement are generations of living things produced; and in like manner are tempests and meteors engendered by the circular movement, and by the approach and recession of the Sun.

And similarly does it come to pass in the body, through the movement of the blood, that the various parts are nourished, cherished, quickened by the warmer, more perfect, vaporous, spirituous, and, as I may say, alimentive blood; which, on the other hand, owing to its contact with these parts, becomes cooled, coagulated, and, so to speak, effete. It then returns to its sovereign the heart, as if to its source, or to the inmost home of the body, there to recover its state of excellence or perfection. Here it renews its fluidity, natural heat, and becomes powerful, fervid, a kind of treasury of life, and impregnated with spirits,

it might be said with balsam. Thence it is again dispersed. All this depends on the movement and action of the heart.

The heart, consequently, is the beginning of life ; the Sun of the Microcosm, even as the Sun in his turn might well be designated the heart of the World ; for it is the heart by whose virtue and pulse the blood is moved, perfected, and made nutrient, and is preserved from corruption and coagulation ; it is the household divinity which, discharging its function, nourishes, cherishes, quickens the whole body, and is indeed the foundation of life, the source of all action. But of these things we shall speak more opportunely when we come to speculate upon the final cause of this movement of the heart.

Hence since the veins are the conduits and vessels that transport the blood, they are of two kinds, the cava and the aorta ; and this not by reason of there being two sides of the body, as *Aristotle* has it, but because of the difference of office, not, as is commonly said, in consequence of any diversity of structure, for in many animals, as I have said, the vein does not differ from the artery in the thickness of its walls, but solely in virtue of their distinct functions and uses. A vein and an artery, both styled veins by the ancients, and that not without reason, as *Galen* has remarked, for the artery is the vessel which carries the blood from the heart to the body at large, the vein of the present day bringing it back from the general system to the heart ; the former is the conduit from, the latter the channel to, the heart ; the latter contains the cruder, effete blood, rendered unfit for nutrition ; the former transmits the digested, perfect, peculiarly nutritive fluid.

Chapter IX.

That there is a Circulation of the Blood is Confirmed from the First Proposition.

BUT lest anyone should say that we give them words only, and make mere specious assertions without any foundation, and desire to innovate without sufficient cause, three points present themselves for confirmation, which being stated, I conceive that the truth I contend for will follow necessarily, and appear as a thing obvious to all. First,—the blood is incessantly transmitted by the action of the heart from the vena cava to the arteries in such quantity that it cannot be supplied from the ingesta, and in such a manner that the whole must very quickly pass through the organ ; Second,—the blood under the influence of the arterial pulse enters and is impelled in a continuous, equable, and incessant stream through every part and member of the body, in much larger quantity than were sufficient for nutrition, or than the whole mass of fluids could supply; Third,—the veins in like manner return this blood incessantly to the heart from parts and members of the body. These points proved, I conceive it will be manifest that the blood circulates, revolves, propelled and then returning, from the heart to the extremities, from the extremities to the heart, and thus that it performs a kind of circular movement.

Let us assume either arbitrarily or from experiment, the quantity of blood which the left ventricle of the heart will contain when distended, to be, say two ounces, three ounces, or one ounce and a half—in the dead body I have found it to hold upwards of two ounces. Let us assume further, how much less the heart will hold in the contracted than in the dilated state ; and how much blood it will project into the aorta upon each contraction ;—and all the world allows that with the systole something is always projected, a necessary consequence demonstrated in the third chapter, and obvious from the structure of

the valves; and let us suppose as approaching the truth that the fourth, or fifth, or sixth, or even but the eighth part of its charge is thrown into the artery at each contraction ; this would give either half an ounce, or three drachms, or one drachm of blood as propelled by the heart at each pulse into the aorta; which quantity, by reason of the valves at the root of the vessel, can by no means return into the ventricle. Now in the course of half an hour, the heart will have made more than one thousand beats, in some as many as two, three, and even four thousand. Multiplying the number of drachms propelled by the number of pulses, we shall have either one thousand half ounces, or one thousand times three drachms, or a like proportional quantity of blood, according to the amount which we assume as propelled with each stroke of the heart, sent from this organ into the artery ; a larger quantity in every case than is contained in the whole body! In the same way, in the sheep or dog, say that but a single scruple of blood passes with each stroke of the heart, in one half hour we should have one thousand scruples, or about three pounds and a half of blood injected into the aorta; but the body of neither animal contains above four pounds of blood, a fact which I have myself ascertained in the case of the sheep.

Upon this supposition, therefore, assumed merely as a ground for reasoning, we see the whole mass of blood passing through the heart, from the veins to the arteries, and in like manner through the lungs.

But let it be said that this does not take place in half an hour, but in an hour, or even in a day ; any way it is still manifest that more blood passes through the heart in consequence of its action, than can either be supplied by the whole of the ingesta, or than can be contained in the veins at the same moment.

Nor can it be allowed that the heart in contracting sometimes propels and sometimes does not propel, or at most propels but very little, a mere nothing, or an imaginary something : all this, indeed, has already been refuted, and is, besides, contrary both to sense and reason. For if it be a necessary effect of the dilatation of the heart that its ventricles become filled with

blood, it is equally so that, contracting, these cavities should expel their contents; and this not in any trifling measure. For neither are the conduits small, nor the contractions few in number, but frequent, and always in some certain proportion, whether it be a third or a sixth, or an eighth, to the total capacity of the ventricles, so that a like proportion of blood must be expelled, and a like proportion received with each stroke of the heart, the capacity of the ventricle contracted always bearing a certain relation to the capacity of the ventricle when dilated. And since in dilating, the ventricles cannot be supposed to get filled with nothing, or with an imaginary something, so in contracting they never expel nothing or aught imaginary, but always a certain something, *viz.*, blood, in proportion to the amount of the contraction. Whence it is to be concluded, that if at one stroke the heart in man, the ox or the sheep, ejects but a single drachm of blood, and there are one thousand strokes in half an hour, in this interval there will have been ten pounds five ounces expelled: if with each stroke two drachms are expelled, the quantity would of course amount to twenty pounds and ten ounces; if half an ounce, the quantity would come to forty-one pounds and eight ounces; and were there one ounce it would be as much as eighty-three pounds and four ounces; the whole of which, in the course of one half hour, would have been transfused from the veins to the arteries. The actual quantity of blood expelled at each stroke of the heart, and the circumstances under which it is either greater or less than ordinary, I leave for particular determination afterwards, from numerous observations which I have made on the subject.

Meantime this much I know, and would here proclaim to all, that the blood is transfused at one time in larger, at another in smaller quantity; and that the circuit of the blood is accomplished now more rapidly, now more slowly, according to the temperament, age, *&c.*, of the individual, to external and internal circumstances, to naturals and non-naturals,—sleep, rest, food, exercise, affections of the mind, and the like. But, supposing even the smallest quantity of blood to be passed through the heart and the lungs with each pulsation, a vastly greater amount

would still be thrown into the arteries and whole body, than could by any possibility be supplied by the food consumed. It could be furnished in no other way than by making a circuit and returning.

This truth, indeed, presents itself obviously before us when we consider what happens in the dissection of living animals ; the great artery need not be divided, but a very small branch only, (as *Galen* even proves in regard to man), to have the whole of the blood in the body, as well that of the veins as of the arteries, drained away in the course of no long time—some half hour or less. Butchers are well aware of the fact and can bear witness to it ; for, cutting the throat of an ox and so dividing the vessels of the neck, in less than a quarter of an hour they have all the vessels bloodless—the whole mass of blood has escaped The same thing also occasionally occurs with great rapidity in performing amputations and removing tumours in the human subject.

Nor would this argument lose any of its force, did anyone say that in killing animals in the shambles, and performing amputations, the blood escaped in equal, if not perchance in larger quantity by the veins than by the arteries. The contrary of this statement, indeed, is certainly the truth ; the veins, in fact, collapsing, and being without any propelling power, and further, because of the impediment of the valves, as I shall show immediately, pour out but very little blood ; whilst the arteries spirt it forth with force abundantly, impetuously, and as if it were propelled by a syringe. And then the experiment is easily tried of leaving the vein untouched, and only dividing the artery in the neck of a sheep or dog, when it will be seen with what force, in what abundance, and how quickly, the whole blood in the body, of the veins as well as of the arteries is emptied. But the arteries receive blood from the veins in no other way than by transmission through the heart, as we have already seen ; so that if the aorta be tied at the base of the heart, and the carotid or any other artery be opened, no one will now be surprised to find it empty, and the veins only replete with blood.

And now the cause is manifest, why in our dissections we

usually find so large a quantity of blood in the veins, so little in the arteries; why there is much in the right ventricle, little in the left, which probably led the ancients to believe that the arteries (as their name implies) contained nothing but spirits during the life of an animal. Perhaps the true cause of the difference is this, that as there is no passage to the arteries, save through the lungs and heart, when an animal has ceased to breathe and the lungs to move, the blood in the pulmonary artery is prevented from passing into the pulmonary veins, and from thence into the left ventricle of the heart; just as we have already seen the same transit prevented in the embryo, by the want of movement in the lungs and the alternate opening and closing of their minute orifices and invisible pores. But the heart not ceasing to act at the same precise moment as the lungs, but surviving them and continuing to pulsate for a time, the left ventricle and arteries go on distributing their blood to the body at large and sending it into the veins; receiving none from the lungs, however, they are soon exhausted, and left, as it were, empty. But even this fact confirms our views, in no trifling manner, seeing that it can be ascribed to no other than the cause we have just assumed.

Moreover it appears from this that the more frequently or forcibly the arteries pulsate, the more speedily will the body be exhausted of its blood during hemorrhage. Hence, also, it happens, that in fainting fits and in states of alarm, when the heart beats more languidly and less forcibly, hemorrhages are diminished and arrested.

Still further, it is from this, that after death, when the heart has ceased to beat, it is impossible by dividing either the jugular or femoral veins and arteries, by any effort to force out more than one half of the whole mass of the blood. Neither could the butcher ever bleed the carcass effectually did he neglect to cut the throat of the ox which he has knocked on the head and stunned, before the heart had ceased beating.

Finally, we are now in a condition to suspect wherefore it is that no one has yet said anything to the purpose upon the anastomosis of the veins and arteries, either as to where or how it is

effected, or for what purpose. I now enter upon the investigation of the subject.

Chapter X.

The First Position: of the Quantity of Blood passing from the Veins to the Arteries. And that there is a Circuit of the Blood, Freed from Objections, and Further Confirmed by Experiment.

SO far our first position is confirmed, whether the thing be referred to calculation or to experiment and dissection, *viz.*, that the blood is incessantly poured into the arteries in larger quantities than it can be supplied by the food ; so that the whole passing over in a short space of time, it is matter of necessity that the blood perform a circuit, that it return whence it set out.

But if anyone shall here object that a large quantity may pass through and yet no necessity be found for a circulation, that all may come from the meat and drink consumed, and quote as an illustration the abundant supply of milk in the mammæ—for a cow will give three, four, and even seven gallons and more in a day, and a woman two or three pints whilst nursing a child or twins, which must manifestly be derived from the food consumed; it may be answered, that the heart by computation does as much and more in the course of an hour or two.

And if not yet convinced, he shall still insist, that when an artery is divided, a preternatural route is, as it were, opened, and that so the blood escapes in torrents, but that the same thing does not happen in the healthy and uninjured body when no outlet is made ; and that in arteries filled, or in their natural state, so large a quantity of blood cannot pass in so short a space of time as to make any return necessary ;—to all this it may be answered, that from the calculation already made, and

the reasons assigned, it appears, that by so much as the heart in its dilated state contains in addition to its contents in the state of constriction, so much in a general way must it emit upon each pulsation, and in such quantity must the blood pass, the body being entire and naturally constituted.

But in serpents, and several fishes, by tying the veins some way below the heart, you will perceive a space between the ligature and the heart speedily to become empty; so that, unless you would deny the evidence of your senses, you must needs admit the return of the blood to the heart. The same thing will also plainly appear when we come to discuss our second position.

Let us here conclude with a single example, confirming all that has been said, and from which everyone may obtain conviction through the testimony of his own eyes.

If a live snake be laid open, the heart will be seen pulsating quietly, distinctly, for more than an hour, moving like a worm, contracting in its longitudinal dimensions, (for it is of an oblong shape), and propelling its contents. It becomes of a paler colour in the systole, of a deeper tint in the diastole; and almost all things else are seen by which I have already said that the truth I contend for is established, only that here everything takes place more slowly, and is more distinct. This point in particular may be observed more clearly than the noon-day sun: the vena cava enters the heart at its lower part, the artery quits it at the superior part; the vein being now seized either with forceps or between the finger and thumb, and the course of the blood for some space below the heart interrupted, you will perceive the part that intervenes between the fingers and the heart almost immediately to become empty, the blood being exhausted by the action of the heart; at the same time the heart will become of a much paler colour, even in its state of dilatation, than it was before; it is also smaller than at first, from wanting blood; and then it begins to beat more slowly, so that it seems at length as if it were about to die. But the impediment to the flow of blood being removed, instantly the colour and the size of the heart are restored.

If, on the contrary, the artery instead of the vein be compressed or tied, you will observe the part between the obstacle and the heart, and the heart itself, to become inordinately distended, to assume a deep purple or even livid colour, and at length to be so much oppressed with blood that you will believe it about to be choked; but the obstacle removed, all things immediately return to their natural state in colour, size, and impulse.

Here, then, we have evidence of two kinds of death: extinction from deficiency, and suffocation from excess. Examples of both have now been set before you, and you have had opportunity of viewing the truth contended for with your own eyes in the heart.

Chapter XI.

The Second Position is Demonstrated.

THAT this may the more clearly appear to everyone, I have here to cite certain experiments, from which it seems obvious that the blood enters a limb by the arteries, and returns from it by the veins; that the arteries are the vessels carrying the blood from the heart, and the veins the returning channels of the blood to the heart; that in the limbs and extreme parts of the body the blood passes either immediately by anastomosis from the arteries into the veins, or mediately by the pores of the flesh, or in both ways, as has already been said in speaking of the passage of the blood through the lungs whence it appears manifest that in the circuit the blood moves from that place to this place, and from that point to this one; from the centre to the extremities, to wit; and from the extreme parts back again to the centre. Finally, upon grounds of calculation, with the same elements as before, it will be obvious that the quantity can neither be accounted for by the ingesta, nor yet be held necessary to nutrition.

The same thing will also appear in regard to ligatures, an

wherefore they are said to *draw;* though this is neither from the heat, nor the pain, nor the vacuum they occasion, nor indeed from any other cause yet thought of; it will also explain the uses and advantages to be derived from ligatures in medicine, the principle upon which they either suppress or occasion hemorrhage; how they induce sloughing and more extensive mortification in extremities; and how they act in the castration of animals and the removal of warts and fleshy tumours. But it has come to pass, from no one having duly weighed and understood the causes and rationale of these various effects, that though almost all, upon the faith of the old writers, recommend ligatures in the treatment of disease, yet very few comprehend their proper employment, or derive any real assistance from them in effecting cures.

Ligatures are either very tight or of medium tightness. A ligature I designate as tight or perfect when it so constricts an extremity that no vessel can be felt pulsating beyond it. Such a ligature we use in amputations to control the flow of blood; and such also are employed in the castration of animals and the ablation of tumours. In the latter instances, all afflux of nutriment and heat being prevented by the ligature, we see the testes and large fleshy tumours dwindle, die, and finally fall off.

Ligatures of medium tightness I regard as those which compress a limb firmly all round, but short of pain, and in such a way as still suffers a certain degree of pulsation to be felt in the artery beyond them. Such a ligature is in use in blood-letting, an operation which the fillet applied above the elbow is not drawn so tight but that the arteries at the wrist may still be felt beating under the finger.

Now let anyone make an experiment upon the arm of a man, either using such a fillet as is employed in blood-letting, or grasping the limb lightly with his hand, the best subject for it being one who is lean, and who has large veins, and the best time after exercise, when the body is warm, the pulse is full, and the blood carried in larger quantity to the extremities, for all then is more conspicuous; under such circumstances let a ligature be thrown about the extremity, and drawn as tightly as can

be borne it will first be perceived that beyond the ligature, neither in the wrist nor anywhere else, do the arteries pulsate, at the same time that immediately above the ligature the artery begins to rise higher at each diastole, to throb more violently, and to swell in its vicinity with a kind of tide, as if it strove to break through and overcome the obstacle to its current; the artery here, in short, appears as if it were preternaturally full. The hand under such circumstances retains its natural colour and appearance; in the course of time it begins to fall somewhat in temperature, indeed, but nothing is *drawn* into it.

After the bandage has been kept on for some short time in this way, let it be slackened a little, brought to that state or term of medium tightness which is used in bleeding, and it will be seen that the whole hand and arm will instantly become deeply coloured and distended, and the veins show themselves tumid and knotted; after ten or twelve pulses of the artery, the hand will be perceived excessively distended, injected, gorged with blood, *drawn*, as it is said, by this medium ligature, without pain, or heat, or any horror of a vacuum, or any other cause yet indicated.

If the finger be applied over the artery as it is pulsating by the edge of the fillet, at the moment of slackening it, the blood will be felt to glide through, as it were, underneath the finger; and he, too, upon whose arm the experiment is made, when the ligature is slackened, is distinctly conscious of a sensation of warmth, and of something, *viz.*, a stream of blood suddenly making its way along the course of the vessels and diffusing itself through the hand, which at the same time begins to feel hot, and becomes distended.

As we have noted, in connection with the tight ligature, that the artery above the bandage was distended and pulsated, not below it, so, in the case of the moderately tight bandage, on the contrary, do we find that the veins below, never above, the fillet, swell, and become dilated, whilst the arteries shrink; and such is the degree of distension of the veins here, that it is only very strong pressure that will force the blood beyond the fillet, and cause any of the veins in the upper part of the arm to rise.

From these facts it is easy for every careful observer to learn that the blood enters an extremity by the arteries ; for when they are effectually compressed nothing is *drawn* to the member; the hand preserves its colour ; nothing flows into it, neither is it distended ; but when the pressure is diminished, as it is with the bleeding fillet, it is manifest that the blood is instantly thrown in with force, for then the hand begins to swell ; which is as much as to say, that when the arteries pulsate the blood is flowing through them, as it is when the moderately tight ligature is applied; but where they do not pulsate, as, when a tight ligature is used, they cease from transmitting anything, they are only distended above the part where the ligature is applied. The veins again being compressed, nothing can flow through them ; the certain indication of which is, that below the ligature they are much more tumid than above it, and than they usually appear when there is no bandage upon the arm.

It therefore plainly appears that the ligature prevents the return of the blood through the veins to the parts above it, and maintains those beneath it in a state of permanent distension. But the arteries, in spite of its pressure, and under the force and impulse of the heart, send on the blood from the internal parts of the body to the parts beyond the ligature. And herein consists the difference between the tight and the medium ligature, that the former not only prevents the passage of the blood in the veins, but in the arteries also ; the latter, however, whilst it does not prevent the force of the pulse from extending beyond it, and so propelling the blood to the extremities of the body, compresses the veins, and greatly or altogether impedes the return of the blood through them.

Seeing, therefore, that the moderately tight ligature renders the veins turgid and distended, and the whole hand full of blood, I ask, whence is this ? Does the blood accumulate below the ligature coming through the veins, or through the arteries, or passing by certain hidden pores ? Through the veins it cannot come; still less can it come through any system of invisible pores; it must needs then, arrive by the arteries, in conformity with all that has been already said. That it cannot flow in by

the veins appears plainly enough from the fact that the blood cannot be forced towards the heart unless the ligature be removed ; when this is done suddenly all the veins collapse, and disgorge themselves of their contents into the superior parts, the hand at the same time resumes its natural pale colour, the tumefaction and the stagnating blood having disappeared.

Moreover, he whose arm or wrist has thus been bound for some little time with the medium bandage, so that it has not only got swollen and livid but cold, when the fillet is undone is aware of something cold making its way upwards along with the returning blood, and reaching the elbow or the axilla. And I have myself been inclined to think that this cold blood rising upwards to the heart was the cause of the fainting that often occurs after blood-letting : fainting frequently supervenes even in robust subjects, and mostly at the moment of undoing the fillet, as the vulgar say, from the turning of the blood.

Further, when we see the veins below the ligature instantly swell up and become gorged, when from extreme tightness it is somewhat relaxed, the arteries meantime continuing unaffected, this is an obvious indication that the blood passes from the arteries into the veins, and not from the veins into the arteries, and that there is either an anastomosis of the two orders of vessels, or pores in the flesh and solid parts generally that are permeable by the blood. It is further an indication that the veins have frequent communications with one another, because they all become turgid together, whilst under the medium ligature applied above the elbow ; and if any single small vein be pricked with a lancet, they all speedily shrink, and disburthening themselves into this they subside almost simultaneously.

These considerations will enable anyone to understand the nature of the attraction that is exerted by ligatures, and perchance of fluxes generally ; how, for example, when the veins when compressed by a bandage of medium tightness applied above the elbow, the blood cannot escape, whilst it still continues to be driven in, by the forcing power of the heart, by which the parts are of necessity filled, gorged with blood. And how

should it be otherwise? Heat and pain and a vacuum draw, indeed; but in such wise only that parts are filled, not preternaturally distended or gorged, and not so suddenly and violently overwhelmed with the charge of blood forced in upon them, that the flesh is lacerated and the vessels ruptured. Nothing of the kind as an effect of heat, or pain, or the vacuum force, is either credible or demonstrable.

Besides, the ligature is competent to occasion the afflux in question without either pain, or heat, or a vacuum. Were pain in any way the cause, how should it happen that, with the arm bound above the elbow, the hand and fingers should swell below the bandage. and their veins become distended? The pressure of the bandage, certainly prevents the blood from getting there by the veins. And then, wherefore is there neither swelling nor repletion of the veins, nor any sign or symptom of attraction or afflux, above the ligature? But this is the obvious cause of the preternatural attraction and swelling below the bandage, and in the hand and fingers, that the blood is entering abundantly, and with force, but cannot pass out again.

Now is not this the cause of all tumefaction, as indeed *Avicenna* has it, and of all oppressive redundancy in parts, that the access to them is open, but the egress from them is closed? Whence it comes that they are gorged and tumefied. And may not the same thing happen in local inflammations, where, so long as the swelling is on the increase, and has not reached its extreme term, a full pulse is felt in the part, especially when the disease is of the more acute kind, and the swelling usually takes place most rapidly. But these are matters for after discussion. Or does this, which occurred in my own case, happen from the same cause. Thrown from a carriage upon one occasion, I struck my forehead a blow upon the place where a twig of the artery advances from the temple, and immediately, within the time in which twenty beats could have been made, I felt a tumour the size of an egg developed, without either heat or any great pain; the near vicinity of the artery had caused the blood to be effused into the bruised part with unusual force and velocity.

And now, too, we understand why in phlebotomy we apply our ligature above the part that is punctured, not below it; did the flow come from above, not from below, the constriction in this case would not only be of no service, but would prove a positive hinderance; it would have to be applied below the orifice, in order to have the flow more free, did the blood descend by the veins from superior to inferior parts; but as it is elsewhere forced through the extreme arteries into the extreme veins, and the return in these last is opposed by the ligature, so do they fill and swell, and being thus filled and distended, they are made capable of projecting their charge with force, and to a distance, when any one of them is suddenly punctured; but the ligature being slackened, and the returning channels thus left open, the blood forthwith no longer escapes, save by drops; and, as all the world knows, if in performing phlebotomy the bandage be either slackened too much or the limb be bound too tightly, the blood escapes without force, because in the one case the returning channels are not adequately obstructed; in the other the channels of influx, the arteries, are impeded.

Chapter XII.

That there is a Circulation of the Blood is shown from the Second Position Demonstrated.

IF these things be so, another point which I have already referred to, *viz.*, the continual passage of the blood through the heart will also be confirmed. We have seen, that the blood passes from the arteries into the veins, not from the veins into the arteries; we have seen, further, that almost the whole of the blood may be withdrawn from a puncture made in one of the cutaneous veins of the arm if a bandage properly applied be used; we have seen, still further, that the blood flows so freely and rapidly that not only is the whole quantity which was contained in the arm beyond the ligature, and before the

puncture was made, discharged, but the whole which is contained in the body, both that of the arteries and that of the veins.

Whence we must admit, first, that the blood is sent along with an impulse, and that it is urged with force below the ligature; for it escapes with force, which force it receives from the pulse and power of the heart; for the force and movement of the blood are derived from the heart alone. Second, that the afflux proceeds from the heart, and through the heart by a course from the great veins; for it gets into the parts below the ligature through the arteries, not through the veins; and the arteries nowhere receive blood from the veins, nowhere receive blood save and except from the left ventricle of the heart. Nor could so large a quantity of blood be drawn from one vein (a ligature having been duly applied), nor with such impetuosity, such readiness, such celerity, unless through the medium of the impelling power of the heart.

But if all things be as they are now represented, we shall feel ourselves at liberty to calculate the quantity of the blood, and to reason on its circular movement. Should anyone, for instance, in performing phlebotomy, suffer the blood to flow in the manner it usually does, with force and freely, for some half hour or so, no question but that the greatest part of the blood being abstracted, faintings and syncopes would ensue, and that not only would the arteries but the great veins also be nearly emptied of their contents. It is only consonant with reason to conclude that in the course of the half hour hinted at, so much as has escaped has also passed from the great veins through the heart into the aorta. And further, if we calculate how many ounces flow through one arm, or how many pass in twenty or thirty pulsations under the medium ligature, we shall have some grounds for estimating how much passes through the other arm in the same space of time: how much through both lower extremities, how much through the neck on either side, and through all the other arteries and veins of the body, all of which have been supplied with fresh blood, and as this blood must have passed through the lungs and ventricles of the heart, and must have come from the great veins,—we shall perceive that a circu-

lation is absolutely necessary, seeing that the quantities hinted at cannot be supplied immediately from the ingesta, and are vastly more than can be requisite for the mere nutrition of the parts.

It is still further to be observed, that in practising phlebotomy the truths contended for are sometimes confirmed in another way; for having tied up the arm properly, and made the puncture duly, still, if from alarm or any other causes, a state of faintness supervenes, in which the heart always pulsates more languidly, the blood does not flow freely, but distils by drops only. The reason is, that with the somewhat greater than usual resistance offered to the transit of the blood by the bandage, coupled with the weaker action of the heart, and its diminished impelling power, the stream cannot make its way under the ligature; and further, owing to the weak and languishing state of the heart, the blood is not transferred in such quantity as wont from the veins to the arteries through the sinuses of that organ. So also, and for the same reasons, are the menstrual fluxes of women, and indeed hemorrhages of every kind, controlled. And now, a contrary state of things occurring, the patient getting rid of his fear and recovering his courage, the pulse strength is increased, the arteries begin again to beat with greater force, and to drive the blood even into the part that is bound; so that the blood now springs from the puncture in the vein, and flows in a continuous stream.

Chapter XIII.

The Third Position is Confirmed: and the Circulation of the Blood is Demonstrated from it.

THUS far we have spoken of the quantity of blood passing through the heart and the lungs in the centre of the body, and in like manner from the arteries into the veins in the peripheral parts and the body at large. We have yet to explain, however, in what manner the

blood finds its way back to the heart from the extremities by the veins, and how and in what way these are the only vessels that convey the blood from the external to the central parts; which done, I conceive that the three fundamental propositions laid down for the circulation of the blood will be so plain, so well established, so obviously true, that they may claim general credence. Now the remaining position will be made sufficiently clear from the valves which are found in the cavities of the veins themselves, from the uses of these, and from experiments cognizable by the senses.

The celebrated *Hieronymus Fabricius* of *Aquapendente*, a most skilful Anatomist, and venerable old man, or, as the learned *Riolan* will have it, *Jacobus Silvius*, first gave representations of the valves in the veins, which consist of raised or loose portions of the inner membranes of these vessels, of extreme delicacy, and a sigmoid or semilunar shape. They are situated at different distances from each other, and diversely in different individuals; they are connate at the sides of the veins; they are directed upwards or towards the trunks of the veins; the two—for there are for the most part two together—regard each other, mutually touch, and are so ready to come into contact by their edges, that if anything attempt to pass from the trunks into the branches of the veins, or from the greater vessels into the less, they completely prevent it; they are further so arranged, that the horns of those that succeed are opposite the middle of the convexity of those that precede, and so on alternately.

The discoverer of these valves did not rightly understand their use, nor have succeeding Anatomists added anything to our knowledge: for their office is by no means explained when we are told that it is to hinder the blood, by its weight, from all flowing into inferior parts; for the edges of the valves in the jugular veins hang downwards, and are so contrived that they prevent the blood from rising upwards; the valves, in a word, do not invariably look upwards, but always towards the trunks of the veins, invariably towards the seat of the heart. I, and indeed others, have sometimes found valves in the emulgent veins, and in those of the mesentery, the edges of which were directed

towards the vena cava and vena portæ. Let it be added that there are no valves in the arteries, and that dogs, oxen, *&c.*, have invariably valves at the divisions of their crural veins, in the veins that meet towards the top of the os sacrum, and in those branches which come from the haunches, in which no such effect of gravity from the erect position was to be apprehended. Neither are there valves in the jugular veins for the purpose of guarding against apoplexy, as some have said ; because in sleep the head is more apt to be influenced by the contents of the carotid arteries. Neither are the valves present, in order that the blood may be retained in the divarications or smaller trunks and minuter branches, and not be suffered to flow entirely into the more open and capacious channels ; for they occur where there are no divarications : although it must be owned that they are most frequent at the points where branches join. Neither do they exist for the purpose of rendering the current of blood more slow from the centre of the body ; for it seems likely that the blood would be disposed to flow with sufficient slowness of its own accord, as it would have to pass from larger into continually smaller vessels, being separated from the mass and fountain head, and attaining from warmer into colder places.

But the valves are solely made and instituted lest the blood should pass from the greater into the lesser veins, and either rupture them or cause them to become varicose ; lest, instead of advancing from the extreme to the central parts of the body, the blood should rather proceed along the veins from the centre to the extremities ; but the delicate valves, while they readily open in the right direction, entirely prevent all such contrary movement, being so situated and arranged, that if anything escapes, or is less perfectly obstructed by the cornua of the one above, the fluid passing, as it were, by the chinks between the cornua, it is immediately received on the convexity of the one beneath, which is placed transversely with reference to the former, and so is effectually hindered from getting any further.

And this I have frequently experienced in my dissections of the veins : if I attempted to pass a probe from the trunk of the veins into one of the smaller branches, whatever care I took I

found it immpossible to introduce it far any way, by reason of the valves ; whilst, on the contrary, it was most easy to push it along in the opposite direction, from without inwards, or from the branches towards the trunks and roots. In many places two valves are so placed and fitted, that when raised they come exactly together in the middle of the vein, and are there united by the contact of their margins ; and so accurate is the adaptation, that neither by the eye nor by any other means of examination, can the slightest chink along the line of contact be perceived. But if the probe be now introduced from the extreme towards the more central parts, the valves, like the floodgates of a river, give way, and are most readily pushed aside. The effect of this arrangement plainly is to prevent all movement of the blood from the heart and vena cava, whether it be upwards towards the head, or downwards towards the feet, or to either side towards the arms, not a drop can pass ; all movement of the blood, beginning in the larger and tending towards the smaller veins, is opposed and resisted by them ; whilst the movement that proceeds from the lesser to end in the larger branches is favoured, or, at all events, a free and open passage is left for it.

But that this truth may be made the more apparent, let an arm be tied up above the elbow as if for phlebotomy (A, A, fig. 1).* At intervals in the course of the veins, especially in labouring people and those whose veins are large, certain knots or elevations (B, C, D, E, F,) will be perceived, and this not only at the places where a branch is received (E, F), but also where none enters (C, D) : these knots or risings are all formed by valves, which thus show themselves externally. And now if you press the blood from the space above one of the valves, from H to O, (fig. 2,) and keep the point of a finger upon the vein inferiorly, you will see no influx of blood from above ; the portion of the vein between the point of the finger and the valve O will be obliterated ; yet will the vessel continue sufficiently distended above that valve (O, G). The blood being thus pressed out, and the vein emptied, if you now apply a finger of the other hand

[* See plates given in facsimile, *ante.*]

upon the distended part of the vein above the valve O, (fig. 3,) and press downwards, you will find that you cannot force the blood through or beyond the valve ; but the greater effort you use, you will only see the portion of vein that is between the finger and the valve become more distended, that portion of the vein which is below the valve remaining all the while empty (H, O, fig. 3).

It would therefore appear that the function of the valves in the veins is the same as that of the three sigmoid valves which we find at the commencement of the aorta and pulmonary artery, *viz.*, to prevent all reflux of the blood that is passing over them.

Further, the arm being bound as before, and the veins looking full and distended, if you press at one part in the course of a vein with the point of a finger (L, fig. 4), and then with another finger streak the blood upwards beyond the next valve (N), you will perceive that this portion of the vein continues empty (L N), and that the blood cannot retrograde, precisely as we have already seen the case to be in fig. 2 ; but the finger first applied (H, fig. 2, L, fig. 4), being removed, immediately the vein is filled from below, and the arm becomes as it appears at D C, fig. 1. That the blood in the veins therefore proceeds from inferior or more remote to superior parts and towards the heart, moving in these vessels in this and not in the contrary direction, appears most obviously. And although in some places the valves, by not acting with such perfect accuracy, or where there is but a single valve, do not seem totally to prevent the passage of the blood from the centre, still the greater number of them plainly do so; and then, where things appear contrived more negligently, this is compensated either by the more frequent occurrence or more perfect action of the succeeding valves, or in some other way: the veins, in short, as they are the free and open conduits of the blood returning *to* the heart, so are they effectually prevented from serving as its channels of distribution *from* the heart.

But this other circumstance has to be noted : The arm being bound, and the veins made turgid, and the valves prominent, as before, apply the thumb or finger over a vein in the situation of

one of the valves in such a way as to compress it, and prevent any blood from passing upwards from the hand; then, with a finger of the other hand, streak the blood in the vein upwards till it has passed the next valve above (N, fig. 4,) the vessel now remains empty; but the finger at L being removed for an instant, the vein is immediatly filled from below; apply the finger again, and having in the same manner streaked the blood upwards, again remove the finger below, and again the vessel becomes distended as before; and this repeat, say a thousand times, in a short space of time. And now compute the quantity of blood which you have thus pressed up beyond the valve, and then multiplying the assumed quantity by one thousand, you will find that so much blood has passed through a certain portion of the vessel; and I do now believe that you will find yourself convinced of the circulation of the blood, and of its rapid movement. But if in this experiment you will say that a violence is done to Nature, I do not doubt but that, if you proceed in the same way, only taking as great a length of vein as possible, and merely remark with what rapidity the blood flows upwards, and fills the vessel from below, you will come to the same conclusion.

Chapter XIV.

Conclusion of the Demonstration of the Circulation.

AND now I may be allowed to give in brief my view of the circulation of the blood, and to propose it for general adoption.

Since all things, both argument and ocular demonstration, show that the blood passes through the lungs and heart by the force of the ventricles, and is sent for distribution to all parts of the body, where it makes its way into the veins and pores of the flesh, and then flows by the veins from the circumference on every side to the centre, from the lesser to the greater veins, and is by them finally discharged into the vena cava and

right auricle of the heart, and this in such a quantity or in such aflux and reflux thither by the arteries, hither by the veins, as cannot possibly be supplied by the ingesta, and is much greater than can be required for mere purposes of nutrition ; it is absolutely necessary to conclude that the blood in the animal body is impelled in a circle, and is in a state of ceaseless movement ; that this is the act or function which the heart performs by means of its pulse ; and that it is the sole and only end of the movement and contraction of the heart.

Chapter XV.

The Circulation of the Blood is Further Confirmed by Probable Reasons.

IT will not be foreign to the subject if I here show further, from certain familiar reasonings, that the circulation is matter both of convenience and necessity. In the first place, since death is a corruption which takes place through deficiency of heat,* and since all living things are warm, all dying things cold, there must be a particular seat and fountain, a kind of home and hearth, where the cherisher of Nature, the original of the native fire, is stored and preserved ; from which heat and life are dispensed to all parts as from a fountain head ; whence sustenance may be derived ; and upon which concoction and nutrition, and all vegetative energy may depend. Now, that the heart is this place, that the heart is the principle of life, and that all passes in the manner just mentioned, I trust no one will deny.

The blood, therefore, required to have movement, and indeed such a movement that it should return again to the heart ; for sent to the external parts of the body far from its fountain, as *Aristotle* says, and without movement, it would become congealed.

* Aristoteles De Respiratione, lib. ii., et iii. : De Part. Animal. et alibi.

For we see movement generating and keeping up heat and spirits under all circumstances, and rest allowing them to escape and be dissipated. The blood, therefore, becoming thick or congealed by the cold of the extreme and outward parts, and robbed of its spirits, just as it is in the dead, it was imperative that from its fount and origin, it should again receive heat and spirits, and all else requisite to its preservation—that, by returning, it should be renovated and restored.

We frequently see how the extremities are chilled by the external cold, how the nose and cheeks and hands look blue, and how the blood, stagnating in them as in the pendent or lower parts of a corpse, becomes of a dusky hue; the limbs at the same time getting torpid, so that they can scarcely be moved, and seem almost to have lost their vitality. Now they can by no means be so effectually, and especially so speedily restored to heat and colour and life, as by a new efflux and contact of heat from its source. But how can parts attract in which the heat and life are almost extinct? Or how should they whose passages are filled with condensed and frigid blood, admit fresh aliment—renovated blood—unless they had first got rid of their old contents? Unless the heart were truly that fountain where life and heat are restored to the refrigerated fluid, and whence new blood, warm, imbued with spirits, being sent out by the arteries, that which has become cooled and effete is forced on, and all the particles recover their heat which was failing, and their vital stimulus well-nigh exhausted.

Hence it is that if the heart be unaffected, life and health may be restored to almost all the other parts of the body; but if the heart be chilled, or smitten with any serious disease, it seems matter of necessity that the whole animal fabric should suffer and fall into decay. When the source is corrupted, there is nothing, as *Aristotle* says,* which can be of service either to it or aught that depends on it. And hence, by the way, it may perchance be why grief, and love, and envy, and anxiety, and all affections of the mind of a similar kind are accompanied with

* De Part. Animal., iii.

emaciation and decay, or with disordered fluids and crudity, which engender all manner of diseases and consume the body of man. For every affection of the mind that is attended with either pain or pleasure, hope or fear, is the cause of an agitation whose influence extends to the heart, and there induces change from the natural constitution, in the temperature, the pulse and the rest, which impairing all nutrition in its source and abating the powers at large, it is no wonder that various forms of incurable disease in the extremities and in the trunk are the consequence, inasmuch as in such circumstances the whole body labours under the effects of vitiated nutrition and a want of native heat.

Moreover, when we see that all animals live through food digested in their interior, it is imperative that the digestion and distribution be perfect; and, as a consequence, that there be a place and receptacle where the aliment is perfected and whence it is distributed to the several members. Now this place is the heart, for it is the only organ in the body which contains blood for the general use; all the others receive it merely for their peculiar or private advantage, just as the heart also has a supply for its own especial behoof in its coronary veins and arteries. But it is of the store which the heart contains in its auricles and ventricles that I here speak. Then the heart is the only organ which is so situated and constituted that it can distribute the blood in due proportion to the several parts of the body, the quantity sent to each being according to the dimensions of the artery which supplies it, the heart serving as a magazine or fountain ready to meet its demands.

Further, a certain impulse or force, as well as an impeller or forcer, such as the heart, was required to effect this distribution and movement of the blood; both because the blood is disposed from slight causes, such as cold, alarm, horror, and the like, to collect in its source, to concentrate like parts to a whole, or the drops of water spilt upon a table to the mass of liquid; and because it is forced from the capillary veins into the smaller ramifications, and from these into the larger trunks by the movement of the extremities and the compression of the muscles generally.

The blood is thus more disposed to move from the circumference to the centre than in the opposite direction, even were there no valves to oppose its movement; wherefore, that it may leave its source and enter more confined and colder channels, and flow against the direction to which it spontaneously inclines, the blood requires both force and an impelling power. Now such is the heart and the heart alone, and that in the way and manner already explained.

Chapter XVI.

The Circulation of the Blood is Further Proved from Certain Consequences.

THERE are still certain phenomena, which, taken as consequences of this truth assumed as proven, are not without their use in exciting belief, as it were, *à posteriore;* and which, although they may seem to be involved in much doubt and obscurity, nevertheless readily admit of having reasons and causes assigned for them. Of such a nature are those that present themselves in connection with contagions, poisoned wounds, the bites of serpents and rabid animals, lues venerea and the like. We sometimes see the whole system contaminated, though the part first infected remains sound; the lues venerea has occasionally made its attack with pains in the shoulders and head, and other symptoms, the genital organs being all the while unaffected; and then we know that the wound made by a rabid dog having healed, fever and a train of disastrous symptoms may nevertheless supervene. Whence it appears that the contagion impressed upon or deposited in a particular part, is by and by carried by the returning current of blood to the heart, and by that organ is sent to contaminate the whole body.

In tertian fever, the morbific cause seeking the heart in the first instance, and hanging about the heart and lungs, renders

the patient short-winded, disposed to sighing, and indisposed to exertion, because the vital principle is oppressed and the blood forced into the lungs and rendered thick does not pass through their substance, (as I have myself seen in opening the bodies of those who had died in the beginning of the attack,) when the pulse is always frequent, small, and occasionally irregular ; but the heat increasing, the matter becoming attenuated, the passages forced, and the transit made, the whole body begins to rise in temperature, and the pulse becomes fuller and stronger. The febrile paroxysm is fully formed, whilst the preternatural heat kindled in the heart is thence diffused by the arteries through the whole body along with the morbific matter, which is in this way overcome and dissolved by Nature.

When we perceive, further, that medicines applied externally exert their influence on the body just as if they had been taken internally, the truth we are contending for is confirmed. Colocynth and aloes in this way move the belly, cantharides excites the urine, garlic applied to the soles of the feet assists expectoration, cordials strengthen, and an infinite number of examples of the same kind might be cited. Perhaps it will not, therefore, be found unreasonable, if we say that the veins, by means of their orifices, absorb some of the things that are applied externally and carry this inwards with the blood, not otherwise, it may be, than those of the mesentery imbibe the chyle from the intestines and carry it mixed with the blood to the liver. For the blood entering the mesentery by the cœliac artery, and the superior and inferior mesenterics, proceeds to the intestines, from which, along with the chyle that has been attracted into the veins, it returns by their numerous ramifications into the vena portæ of the liver, and from this into the vena cava, and this in such wise that the blood in these veins has the same colour and consistency as in other veins, in opposition to what many believe to be the fact. Nor indeed can we imagine two contrary movements in any capillary system—the chyle upwards, the blood downwards. This could scarcely take place, and must be held as altogether improbable. But is not the thing rather arranged as it is by the consummate providence of Nature ? For were the chyle mingled

with the blood, the crude with the digested, in equal proportions, the result would not be concoction, transmutation, and sanguification, but rather, and because they are severally active and passive, a mixture or combination, or medium compound of the two, precisely as happens when wine is mixed with water and syrup. But when a very minute quantity of chyle is mingled with a very large quantity of circulating blood, a quantity of chyle that bears no kind of proportion to the mass of blood, the effect is the same, as *Aristotle* says, as when a drop of water is added to a cask of wine, or the contrary; the mass does not then present itself as a mixture, but is still sensibly either wine or water. So in the mesenteric veins of an animal we do not find either chyme or chyle and blood, blended together or distinct, but only blood, the same in colour, consistency, and other sensible properties, as it appears in the veins generally. Still as there is a certain though small and inappreciable proportion of chyle or incompletely digested matter mingled with this blood, Nature has interposed the liver, in whose meandering channels it suffers delay and undergoes additional change, lest arriving prematurely and crude at the heart, it should oppress the vital principle. Hence in the embryo, there is almost no use for the liver, but the umbilical vein passes directly through, a foramen or anastomosis existing from the vena portæ. The blood returns from the intestines of the fœtus, not through the liver, but into the umbilical vein mentioned, and flows at once into the heart, mingled with the natural blood which is returning from the placenta; whence also it is that in the development of the fœtus the liver is one of the organs that is last formed. I have observed all the members perfectly marked out in the human fœtus, even the genital organs, whilst there was yet scarcely any trace of the liver. And indeed at the period when all the parts, like the heart itself in the beginning, are still white, and except in the veins there is no appearance of redness, you shall see nothing in the seat of the liver but a shapeless collection, as it were, of extravasated blood, which you might take for the effects of a contusion or ruptured vein.

But in the incubated egg there are, as it were, two umbilical

vessels, one from the albumen passing entire through the liver, and going straight to the heart; another from the yolk, ending in the vena portæ; for it appears that the chick, in the first instance, is entirely formed and nourished by the white; but by the yolk after it has come to perfection and is excluded from the shell; for this part may still be found in the abdomen of the chick many days after its exclusion, and is a substitute for the milk to other animals.

But these matters will be better spoken of in my observations on the formation of the fœtus, where many propositions, the following among the number, will be discussed: Wherefore is this part formed or perfected first, that last, and of the several members, what part is the cause of another? And there are many points having special reference to the heart, such as wherefore does it first acquire consistency, and appear to possess life, movement, sense, before any other part of the body is perfected, as *Aristotle* says in his third book, 'De partibus Animalium'? And so also of the blood, wherefore does it precede all the rest? And in what way does it possess the vital and animal principle, and show a tendency to movement, and to be impelled hither and thither, the end for which the heart appears to be made? In the same way, in considering the pulse, why should one kind of pulse indicate death, another recovery? And so of all the other kinds of pulse, what may be the cause and indication of each? Likewise we must consider the reason of crises and natural critical discharges; of nutrition, and especially the distribution of the nutriment; and of defluxions of every description. Finally, reflecting on every part of medicine, physiology, pathology, semeiotics, and therapeutics, when I see how many questions can be answered, how many doubts resolved, how much obscurity illustrated by the truth we have declared, the light we have made to shine, I see a field of such vast extent in which I might proceed so far, and expatiate so widely, that this my tractate would not only swell out into a volume, which was beyond my purpose, but my whole life, perchance, would not suffice for its completion.

In this place, therefore, and that indeed in a single chapter, I shall endeavour only to refer the various particulars that present

themselves in the dissection of the heart and arteries to their several uses and causes; for so I shall meet with many things which receive light from the truth I have been contending for, and which, in their turn, render it more obvious. And indeed I would have it confirmed and illustrated by anatomical arguments above all others.

There is but a single point which indeed would be more correctly placed among our observations on the use of the spleen, but which it will not be altogether impertinent to notice in this place incidentally. From the splenic branch which passes into the pancreas, and from the upper part, arise the posterior coronary, gastric, and gastroepiploic veins, all of which are distributed upon the stomach in numerous branches and twigs, just as the mesenteric vessels are upon the intestines in like manner, from the inferior part of the same splenic branch, and along the back of the colon and rectum proceed the hemorrhoidal veins. The blood returning by these veins, and bringing the cruder juices along with it, on the one hand from the stomach, where they are thin, watery, and not yet perfectly chylified; on the other thick and more earthy, as derived from the fæces, but all poured into this splenic branch, are duly tempered by the admixture of contraries; and nature mingling together these two kinds of juices, difficult of coction by reason of most opposite defects, and then diluting them with a large quantity of warm blood, (for we see that the quantity returned from the spleen must be very large when we contemplate the size of its arteries,) they are brought to the porta of the liver in a state of higher preparation. The defects of either extreme are supplied and compensated by this arrangement of the veins.

Chapter XVII.

The Movement and Circulation of the Blood are Confirmed from the Particulars Apparent in the Structure of the Heart, and from those Things which Dissection Unfolds.

I DO not find the heart as a distinct and separate part in all animals; some, indeed, such as the zoophytes, have no heart; this is because these animals are coldest, of no great bulk, of soft texture or of a certain uniform sameness or simplicity of structure; among the number I may instance grubs and earth-worms, and those that are engendered of putrefaction and do not preserve their species. These have no heart, as not requiring any impeller of nourishment into the extreme parts; for they have bodies which are connate and homogeneous, and without limbs; so that by the contraction and relaxation of the whole body they assume and expel, move and remove the ailment. Oysters, mussels, sponges, and the whole genus of zoophytes or plant-animals have no heart; for the whole body is used as a heart, or the whole animal is a heart. In a great number of animals, almost the whole tribe of insects, we cannot see distinctly by reason of the smallness of the body; still in bees, flies, hornets, and the like, we can perceive something pulsating with the help of a magnifying-glass; in pediculi, also, the same thing may be seen, and as the body is transparent, the passage of the food through the intestines, like a black spot or stain, may be perceived by the aid of the same magnifying-glass.

But in some of the pale blooded and colder animals, as in snails, whelks, shrimps, and shell-fish, there is a part which pulsates—a kind of vesicle or auricle without a heart—slowly indeed, and not to be perceived except in the warmer season of the year. In these creatures this part is so contrived that it shall pulsate, as there is here a necessity for some impulse to

distribute the nutritive fluid, by reason of the variety of organic parts, or of the density of the substance; but the pulsations occur unfrequently, and sometimes in consequence of the cold not at all, an arrangement the best adapted to them as being of a doubtful nature, so that sometimes they appear to live, sometimes to die; sometimes they show the vitality of an animal, sometimes of a vegetable. This seems also to be the case with the insects which conceal themselves in winter, and lie, as it were, defunct, or merely manifesting a kind of vegetative existence. But whether the same thing happens in the case of certain animals that have red blood, such as frogs, tortoises, serpents, swallows, may be very properly doubted.

In all the larger and warmer animals which have red blood, there was need of an impeller of the nutritive fluid, and that perchance possessing a considerable amount of power. In fishes, serpents, lizards, tortoises, frogs, and others of the same kind there is a heart present, furnished with both an auricle and a ventricle, whence it is perfectly true, as *Aristotle* has observed,* that no sanguineous animal is without a heart, by the impelling power of which the nutritive fluid is forced, both with greater vigour and rapidity to a greater distance; and not merely agitated by an auricle as it is in lower forms. And then in regard to animals that are yet larger, warmer, and more perfect, as they abound in blood, which is always hotter and more spirituous, and which possess bodies of greater size and consistency, these require a larger, stronger, and more fleshy heart, in order that the nutritive fluid may be propelled with yet greater force and celerity. And further, inasmuch as the more perfect animals require a still more perfect nutrition, and a larger supply of native heat, in order that the aliment may be thoroughly concocted and acquire the last degree of perfection, they required both lungs and a second ventricle, which should force the nutritive fluid through them.

Every animal that has lungs has therefore two ventricles to its heart, one right, the other left; and wherever there is a right,

* De Part. Animal., lib. iii.

there also is there a left ventricle ; but the contrary of this does not hold good : where there is a left there is not always a right ventricle. The left ventricle I call that which is distinct in office, not in place from the other, that one namely which distributes the blood to the body at large, not to the lungs only. Hence the left ventricle seems to form the principal part of the heart; situated in the middle, more strongly marked, and constructed with greater care, the heart seems formed for the sake of the left ventricle, and the right but to minister to it. The right neither reaches to the apex of the heart, nor is it nearly of such strength, being three times thinner in its walls, and in some sort jointed on to the left, (as *Aristotle* says ;) though indeed it is of greater capacity, inasmuch as it has not only to supply material to the left ventricle, but likewise to furnish aliment to the lungs.

It is to be observed, however, that all this is otherwise in the embryo, where there is not such a difference between the two ventricles. There, as in a double nut, they are nearly equal in all respects, the apex of the right reaching to the apex of the left, so that the heart presents itself as a sort of double-pointed cone. And this is so, because in the fœtus, as already said, whilst the blood is not passing through the lungs from the right to the left cavities of the heart, it flows by the foramen ovale and ductus arteriosus, directly from the vena cava into the aorta, whence it is distributed to the whole body. Both ventricles have therefore the same office to perform, whence their equality of constitution. It is only when the lungs come to be used, and it is requisite that the passages indicated should be blocked up, that the difference in point of strength and other things between the two ventricles begins to be apparent. In the altered circumstances the right has only to drive the blood through the lungs, whilst the left has to propel it through the whole body.

There are further within the heart numerous braces, in the form of fleshy columns and fibrous bands, which *Aristotle*, in his third book on Respiration, and the Parts of Animals, entitles nerves. These are variously extended, and are either distinct or contained in grooves in the walls and partition, where they

occasion numerous pits or depressions. They constitute a kind of small muscles, which are superadded and supplementary to the heart, assisting it to execute a more powerful and perfect contraction, and so proving subservient to the complete expulsion of the blood. They are in some sort like the elaborate and artful arrangement of ropes in a ship, bracing the heart on every side as it contracts, and so enabling it more effectually and forcibly to expel the charge of blood from its ventricles. This much is plain, at all events, that in some animals they are less strongly marked than in others ; and, in all that have them, they are more numerous and stronger in the left than in the right ventricle; and while some have them present in the left, yet they are absent in the right ventricle. In man they are more numerous in the left than in the right ventricle, more abundant in the ventricles than in the auricles; and occasionally, there appear to be none present in the auricles. They are numerous in the large, more muscular and hardier bodies of countrymen, but fewer in more slender frames and in females.

In those animals in which the ventricles of the heart are smooth within, and entirely without fibres or muscular bands, or anything like hollow pits, as in almost all the smaller birds, the partridge and the common fowl, serpents, frogs, tortoises, and most fishes, there are no chordæ tendineæ, nor bundles of fibres, neither are there any tricuspid valves in the ventricles.

Some animals have the right ventricle smooth internally, but the left provided with fibrous bands, such as the goose, swan, and larger birds ; and the reason is the same here as elsewhere. As the lungs are spongy, and loose, and soft, no great amount of force is required to force the blood through them, therefore the right ventricle is either without the bundles in question, or they are fewer and weaker, and not so fleshy or like muscles. Those of the left ventricle, however, are both stronger and more numerous, more fleshy and muscular, because the left ventricle requires to be stronger, inasmuch as the blood which it propels has to be driven through the whole body. And this, too, is the reason why the left ventricle occupies the middle of the heart, and has parieties three times thicker and stronger than those of

the right. Hence all animals—and among men it is similar—that are endowed with particularly strong frames, and with large and fleshy limbs at a great distance from the heart, have this central organ of greater thickness, strength, and muscularity. This is both obvious and necessary. Those, on the contrary, that are of softer and more slender make have the heart more flaccid, softer, and internally either less or not at all fibrous. Consider, further the use of the several valves, which are all so arranged, that the blood once received into the ventricles of the heart shall never regurgitate, once forced into the pulmonary artery and aorta shall not flow back upon the ventricles. When the valves are raised and brought together they form a three-cornered line, such as is left by the bite of a leech ; and the more they are forced, the more firmly do they oppose the passage of the blood. The tricuspid valves are placed, like gate-keepers, at the entrance into the ventricles from the venæ cavæ and pulmonary veins, lest the blood when most forcibly impelled should flow back. It is for this reason that they are not found in all animals, nor do they appear to have been constructed with equal care in all the animals in which they are found. In some they are more accurately fitted, in others more remissly or carelessly contrived, and always with a view to their being closed under a greater or a slighter force of the ventricle. In the left ventricle, therefore, in order that the occlusion may be more perfect against the greater impulse, there are only two valves, like a mitre, and produced into an elongated cone, so that they come together and touch to their middle ; a circumstance which perhaps led *Aristotle* into the error of supposing this ventricle to be double, the division taking place transversely. For the same reason, and that the blood may not regurgitate upon the pulmonary veins, and thus the force of the ventricle in propelling the blood through the system at large come to be neutralized, it is that these mitral valves excel those of the right ventricle in size and strength, and exactness of closing. Hence, it is essential that there can be no heart without a ventricle, since this must be the source and storehouse of the blood. The same law does not hold good in reference to the brain. For almost

no genus of birds has a ventricle in the brain, as is obvious in the goose and swan, the brains of which nearly equal that of a rabbit in size; now rabbits have ventricle in the brain, whilst the goose has none. In like manner, wherever the heart has a single ventricle, there is an auricle appended, flaccid, membranous, hollow, filled with blood; and where there are two ventricles, there are likewise two auricles. On the other hand, some animals have an auricle without any ventricle; or at all events they have a sac analogous to an auricle; or the vein itself, dilated at a particular part, performs pulsations, as is seen in hornets, bees, and other insects, which certain experiments of my own enable me to demonstrate have not only a pulse, but a respiration in that part which is called the tail, whence it is that this part is elongated and contracted now more rarely, now more frequently, as the creature appears to be blown and to require a larger quantity of air. But of these things, more in our Treatise on Respiration.

It is in like manner evident that the auricles pulsate, contract, as I have said before, and throw the blood into the ventricles; so that wherever there is a ventricle an auricle is necessary, not merely that it may serve, according to the general belief, as a source and magazine for the blood: for what were the use of its pulsations had it only to contain? The auricles are prime movers of the blood, especially the right auricle, which, as already said, is 'the first to live, the last to die;' whence they are subservient to sending the blood into the ventricles, which, contracting continuously, more readily and forcibly expel the blood already in movement; just as the ball-player can strike the ball more forcibly and further if he takes it on the rebound than if he simply threw it. Moreover, and contrary to the general opinion, since neither the heart nor anything else can dilate or distend itself so as to draw anything into its cavity during the diastole, unless, like a sponge, it has been first compressed, and is returning to its primary condition; but in animals all local movement proceeds from, and has its origin in the contraction of some part: consequently it is by the contraction of the auricles that the blood is thrown into the ventricles, as I have already shown, and

from there, by the contraction of the ventricles, it is propelled and distributed. Concerning local movement, it is true that the immediate moving organ in every movement of an animal primarily endowed with a motive spirit (as *Aristotle* has it,*) is contractile; in which way the word *νεῦρον* is derived from *νεύω*, nuto, contraho; and if I am permitted to proceed in my purpose of making a particular demonstration of the organs of movement in animals from observations in my possession, I trust I shall be able to make sufficiently plain how *Aristotle* was acquainted with the muscles, and advisedly referred all movement in animals to the nerves, or to the contractile element, and therefore called those little bands in the heart nerves.

But that we may proceed with the subject which we have in hand, *viz.*, the use of the auricles in filling the ventricles, we should expect that the more dense and compact the heart, the thicker its parieties, the stronger and more muscular must be the auricle to force and fill it, and *vice versa.* Now this is actually so: in some the auricle presents itself as a sanguinolent vesicle, as a thin membrane containing blood, as in fishes, in which the sac that stands in lieu of the auricle, is of such delicacy and ample capacity, that it seems to be suspended or to float above the heart. In those fishes in which the sac is somewhat more fleshy, as in the carp, barbel, tench, and others, it bears a wonderful and strong resemblance to the lungs.

In some men of sturdier frame and stouter make, the right auricle is so strong, and so curiously constructed within, of bands and variously interlacing fibres, that it seems to equal in strength the ventricle of the heart in other subjects; and I must say that I am astonished to find such diversity in this particular in different individuals. It is to be observed, however, that in the fœtus the auricles are out of all proportion large, which is because they are present before the heart makes its appearance or suffices for its office even when it has appeared and they therefore have, as it were, the duty of the whole heart committed to them, as has already been demonstrated. But what I have

* In the book, de Spiritu, and elsewhere.

observed in the formation of the fœtus as before remarked (and *Aristotle* had already confirmed all in studying the incubated egg,) throws the greatest light and likelihood upon the point. Whilst the fœtus is yet in the form of a soft worm, or, as is commonly said, in the milk, there is a mere bloody point or pulsating vesicle, a portion apparently of the umbilical vein, dilated at its commencement or base. Afterwards, when the outline of the fœtus is distincly indicated, and it begins to have greater bodily consistence, the vesicle in question becomes more fleshy and stronger, changes its position, and passes into the auricles, above which the body of the heart begins to sprout, though as yet it apparently performs no office. When the fœtus is further advanced, when the bones can be distinguished from the fleshy parts, and movements take place, then it also has a heart which pulsates, and as I have said, throws blood by either ventricle from the vena cava into the arteries.

Thus Nature, ever perfect and divine, doing nothing in vain, has neither given a heart where it was not required, nor produced it before its office had become necessary; but by the same stages in the development of every animal, passing through the forms of all, as I may say (ovum, worm, fœtus), it acquires perfection in each. These points will be found elsewhere confirmed by numerous observations on the formation of the fœtus.

Finally, it is not without good grounds that *Hippocrates*, in his book, De Corde, entitles it a muscle; its action is the same, so is its function, *viz.*, to contract and move something else, in this case, the charge of blood.

Further, we can infer the action and use of the heart from the arrangement of its fibres and its general structure as in muscles generally. All Anatomists admit with *Galen* that the body of the heart is made up of various courses of fibres running straight, obliquely, and transversely, with reference to one another; but in a heart which has been boiled the arrangement of the fibres is seen to be different. All the fibres in the parietes and septum are circular, as in the sphincters; those, again, which are in the columns extend lengthwise, and are oblique longitudinally; and so it comes to pass, that when all the fibres contract simul-

taneously, the apex of the cone is pulled towards its base by the columns, the walls are drawn circularly together into a globe, the whole heart in short is contracted, and the ventricles narrowed. It is therefore impossible not to perceive that, as the action of the organ is so plainly contraction, its function is to propel the blood into the arteries.

Nor are we the less to agree with *Aristotle* in regard to the importance of the heart, or to question if it receives sense and movement from the brain, blood from the liver, or whether it be the origin of the veins and of the blood, and such like. They who affirm these propositions, overlook, or do not rightly understand the principal argument, to the effect that the heart is the first part which exists, and that it contains within itself blood, life, sensation, and movement, before either the brain or the liver were created or had appeared distinctly, or, at all events, before they could perform any function. The heart, ready furnished with its proper organs of movement, like a kind of internal creature, existed before the body. The first to be formed, Nature willed that it should afterwards fashion, nourish, preserve, complete the entire animal, as its work and dwelling-place: and as the prince in a kingdom, in whose hands lie the chief and highest authority, rules over all, the heart is the source and foundation from which all strength is derived, on which all strength depends in the animal body.

And many things having reference to the arteries further illustrate and confirm this truth. Why does not the pulmonary vein pulsate, seeing that it is numbered among the arteries? Or wherefore is there a pulse in the pulmonary artery? Because the pulse of the arteries is derived from the impulse of the blood. Why does an artery differ so much from a vein in the thickness and strength of its coats? Because it sustains the shock of the impelling heart and streaming blood. Hence, as perfect Nature does nothing in vain, and suffices under all circumstances, we find that the nearer the arteries are to the heart, the more do they differ from the veins in structure; here they are both stronger and more ligamentous, whilst in extreme parts of the body, such as the feet and hands, the brain, the mesentery, and the testicles,

the two orders of vessels are so much alike that it is impossible to distinguish between them with the eye. Now this is for the following very sufficient reasons: for the more remote the vessels are from the heart, with so much the less force are they distended by the stroke of the heart, which is broken by the great distance at which it is given. Add to this, that the impulse of the heart exerted upon the mass of blood, which must needs fill the trunks and branches of the arteries, is diverted, divided, as it were, and diminished at every subdivision, so that the ultimate capillary divisions of the arteries look like veins, and this not merely in constitution but in function, for they have either no perceptible pulse, or they rarely exhibit one, and never except where the heart beats more violently than usual, or at a part where the minute vessel is more dilated or open than elsewhere. Hence it happens that at times we are aware of a pulse in the teeth, in inflammatory tumours, and in the fingers ; at another time we feel nothing of the sort. By this single symptom I have ascertained for certain that young persons, whose pulses are naturally rapid, were labouring under fever ; and in like manner, on compressing the fingers in youthful and delicate subjects during a febrile paroxysm, I have readily perceived the pulse there. On the other hand, when the heart pulsates more languidly, it is often impossible to feel the pulse not merely in the fingers, but the wrist, and even at the temple, as in persons afflicted with lipothymiæ asphyxia, or hysterical symptoms, and in the debilitated and moribund.

And here surgeons are to be advised that, when the blood escapes with force in the amputation of limbs, in the removal of tumours, and in wounds, it constantly comes from an artery ; not always indeed per saltum, because the smaller arteries do not pulsate, especially if a tourniquet has been applied.

For the same reason the pulmonary artery not only has the structure of an artery, but it does not differ so widely from the veins in the thickness of its walls as does the aorta. The aorta sustains a more powerful shock from the left than the pulmonary artery does from the right ventricle, and the walls of this last vessel are thinner and softer than those of the aorta in the same

proportion as the walls of the right ventricle of the heart are weaker and thinner than those of the left ventricle. In like manner, the lungs are softer and laxer in structure than the flesh and other constituents of the body, and in a similar way the walls of the branches of the pulmonary artery differ from those of the vessels derived from the aorta. And the same proportion in these particulars is universally preserved. The more muscular and powerful men are, the firmer their flesh ; the stronger, thicker, denser, and more fibrous their hearts, the thicker, closer, and stronger are the auricles and arteries. Again, in those animals the ventricles of whose hearts are smooth on their inner surface, without villi or valves, and the walls of which are thin, as in fishes, serpents, birds, and very many genera of animals, the arteries differ little or nothing in the thickness of their coats from the veins.

Further, the reason why the lungs have such ample vessels, both arteries and veins, (for the capacity of the pulmonary veins exceeds that of both the crural and jugular vessels,) and why they contain so large a quantity of blood, as by experience and ocular inspection we know they do, admonished of the fact indeed by *Aristotle*, and not led into error by the appearances found in animals which have been bled to death,—is, because the blood has its fountain, and storehouse, and the workshop of its last perfection in the heart and lungs. Why, in the same way we find in the course of our anatomical dissections the pulmonary vein and left ventricle so full of blood, of the same black colour and clotted character as that with which the right ventricle and pulmonary artery are filled, is because the blood is incessantly passing from one side of the heart to the other through the lungs. Wherefore, in fine, the pulmonary artery has the structure of an artery, and the pulmonary veins have the structure of veins. In function and constitution, and everything else, the first is an artery, the others are veins, contrary to what is commonly believed ; and the reason why the pulmonary artery has so large an orifice, is because it transports much more blood than is requisite for the nutrition of the lungs.

All these appearances, and many others, to be noted in the

course of dissection, if rightly weighed, seem clearly to illustrate and fully to confirm the truth contended for throughout these pages, and at the same time to oppose the vulgar opinion ; for it would be very difficult to explain in any other way to what purpose all is constructed and arranged as we have seen it to be.

FINIS.